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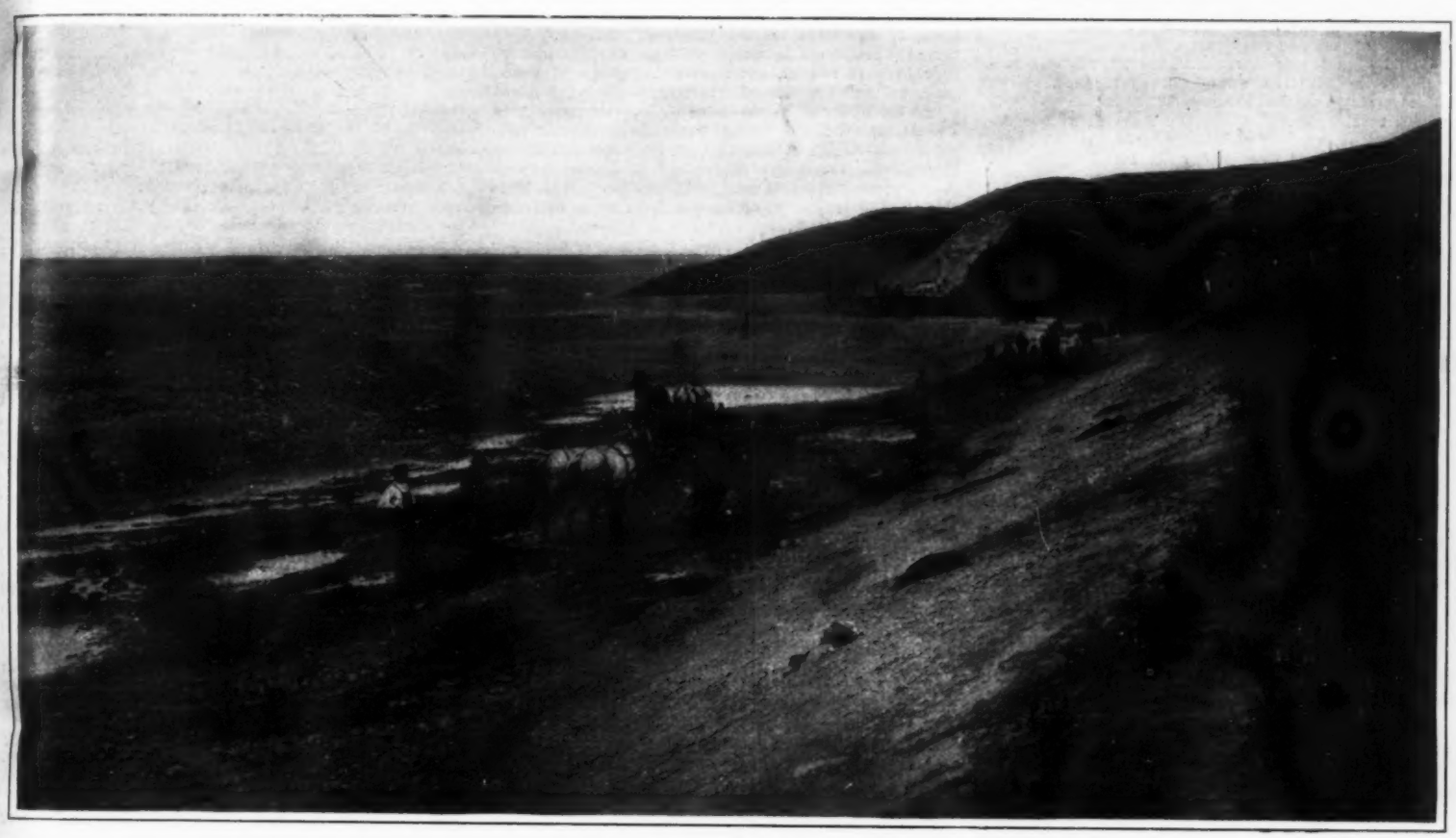
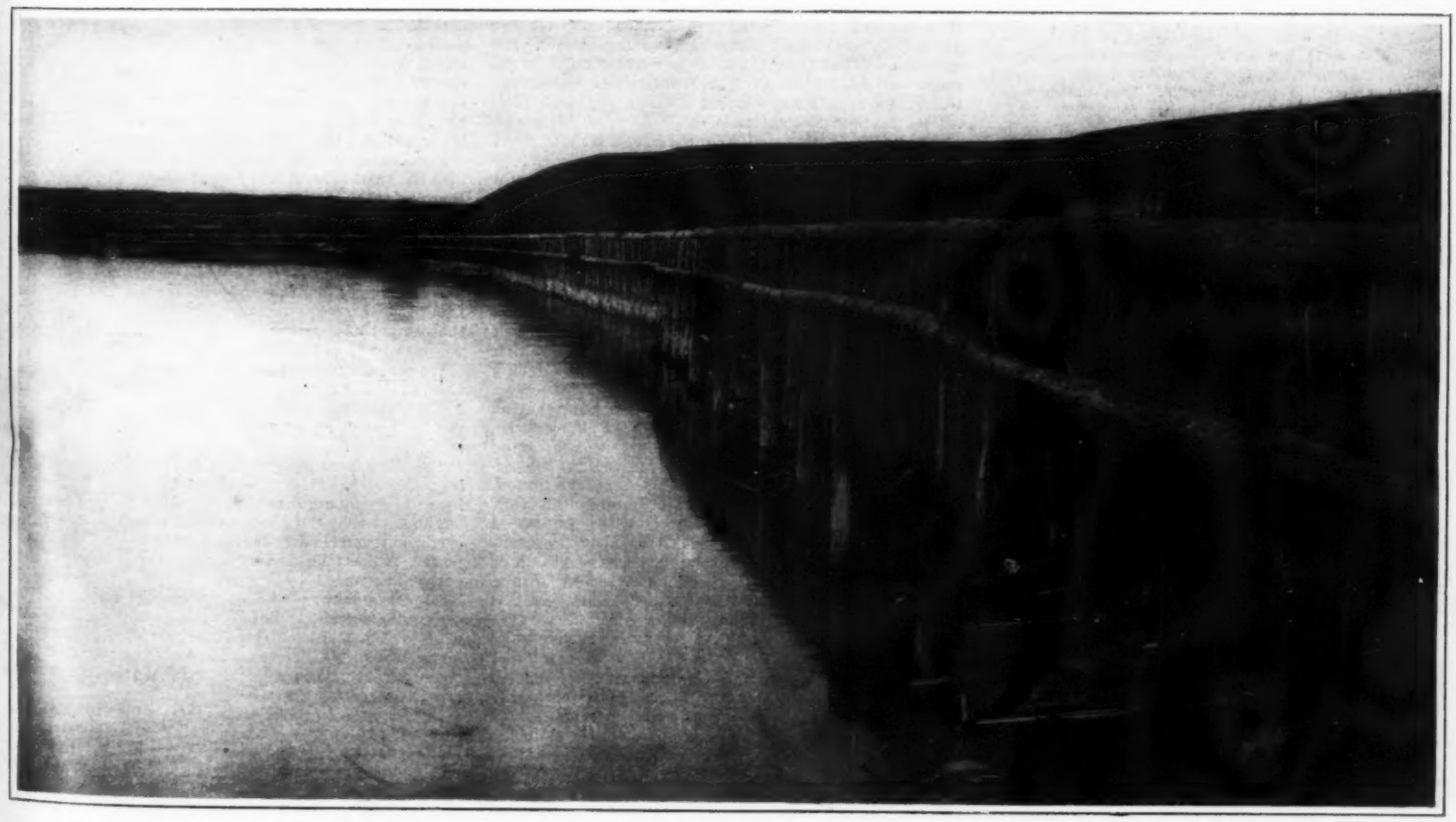


CUTTING THROUGH THE HILLS.



THE BOW RIVER NEAR CALGARY WHERE THE $4,000,000 IRRIGATION PROJECT BEGINS.

IRRIGATION IN WESTERN CANADA.—[SEE PAGE 25700.]

THE NATURE AND ORIGIN OF VOLCANIC HEAT.*

By ELIHU THOMSON.

THE hypothesis of a molten or more or less fluid interior, as possessed by the earth, may now be said to have been abandoned, and along with it the supposition that volcanoes constitute vents for the escape, as a consequence of shrinkage and subsidence, of a portion of the molten content lying everywhere under the solid crust. The hypothesis that the interior of the earth, while in the main solid, has cavities containing melted matter which occasionally is forced out in the form of eruptive outbursts is a kindred one which has found some adherents. But a truly solid interior seems to be demanded by the accepted great rigidity of the body of the earth, and Mallet has put forward the idea that extraordinary pressures exerted to crush the rocks would result in their becoming heated and melted. Evidently, however, mere pressure acting alone, however great, would not suffice for this. Incipient fluidity would substantially put an end to the crushing process and heat generation would stop. The observed high temperatures attained by volcanic products during eruption would not be reached. More recently the thermal effects of volcanoes, and the various results thereof, have been ascribed by one authority to the presence of radium, which, as is known, continuously gives out energy in its breaking up. But volcanic lavas have not been found to be sources of radium or of uranium, the amount of which should be quite large if the supposition is to be given any serious consideration.

The object of this paper is to present a view of the origin of volcanic heat which may possess some elements of novelty and, it is hoped, of rationality. According to this view, much of the heat manifested is due to mechanical work converted into heat, a theory based upon dynamical principles to be later pointed out. Primarily it will be admitted that any substance, gas, liquid or solid, upon which work is done acquires heat in proportion to the energy expended upon it, which heat, if prevented from escaping, at once results in an increase of temperature of the substance. If the mechanical energy so converted be of known amount, we may calculate from the mass and specific heat of the substance or body upon which such energy is expended, the rise in temperature. Even if air at ordinary temperature under high pressure escapes through a tortuous or frictional passage surrounded by a good heat non-conductor, it emerges hot. The higher the pressure and the greater the friction met in the passage the greater the increase. The heating is directly related to the work done upon the mass.

If a liquid be substituted for the air the general result is the same, and the liquid may be made to boil upon its escape. If a somewhat plastic solid like hard pitch be subjected to the process, the energy required will be greatly increased, or the pressure required to force it through the tortuous passage of some length will be great. It may emerge hot and melted if the conditions be properly selected.

If now it be assumed that any solid be subjected to a pressure such as to cause it to flow in a tortuous or restricted channel, it will, in so moving, rise in temperature, and continue so to rise until it has reached a degree of fluidity such as to lessen or practically stop the absorption of energy in moving the mass; or until it escapes from the passage through which it is being impelled. The pressure is but one factor of the energy, the other being the distance through which the pressure acts. The pressure required depends upon the resistance to motion, which in turn is greater with more rigid bodies and greater with increase of distance through which friction is met and overcome. The pressure or force required will be at a maximum when the solid mass starts cold or nearly so and will diminish as the temperature is raised and consequent plasticity or fluidity brought about. A rock mass forced to move under great pressure over distances of thousands of feet must soon become melted in the process. It is not necessary to assume that the mass so heated starts cold. It may start at any temperature at which it possesses sufficient rigidity or viscosity to require the exertion of great force to move it in the assumed restricted or tortuous passage or channel. Great velocity of movement in such passage means of course great energy expenditure and rapid heating. The idea thus outlined may now be applied as an explanation of volcanic phenomena. For example, a hot-water spring may be the result of the water having been forced by high pressure to traverse somewhat porous rock, or to pass through narrow but long fissures in which it is churned for a long time before escaping. In like manner any rock mass which, subjected to very high pressure, begins to flow, must become heated. If its distance of traverse be great enough in a restricted fissure or channel, it must melt, or even become so heated as to partially vaporize when the pressure is relieved, as when it finally escapes. Let it be admitted that the flexures taking place in the earth's crust or in the outer portions of its mass may bring to bear upon deep-seated and perhaps already heated solid rock masses a sufficient pressure to cause them to readjust their positions, and the condition demanded by the theory is present. Such a condition would mean movement of such masses over considerable distances at high pressures, with the final result of the formation of molten streams ready to escape upward from the pressure exerted upon them. A vent would at last form and the rush of the partially melted rocks toward and out of this vent would become a lava flow.

* Science.

These actions would naturally occur at places of flexure such as would tend to form a ridge, and the loading and sinking of sea bottoms as a consequence of sedimentary deposits would be favorable, as is well known, to such flexure as would tend to heavily compress the rocks along the line of flexure deep down from the earth's surface, while relieving or not increasing pressure near the surface. The compressed rock would in general tend to be shifted or made to flow outward at the line of flexure. This view accords well with the facts. Volcanoes exist along lines more or less parallel to or adjacent to sea coasts or along the weak lines in the earth's surface. It will easily be seen that a single volcanic vent or pipe may serve to relieve or provide a point for outflow for the shifting of material over a great length of flexure deep down under the earth's surface. As the flow and fusion would be a somewhat gradual process it may well be that only when the vent is about to open will there be earthquakes and great subterranean noises, more or less local to the place of outbreak. Very probably eruptions in which melted lava does not appear to have a part, but in which steam and gases, sand, or mud are ejected, are nevertheless dependent upon an upthrust of lava or a subterranean lava stream, which never reaches the surface, but the temperature of which is such that, on its reaching hydrous rock strata, the water is evolved as steam at high pressure, which entering superincumbent layers gives rise to mud eruptions, or escapes from vents or fumaroles.

It would be expected that such rock masses as, under pressure, would yield most readily would be the ones to flow and form lavas. They would also be likely to be the more readily fusible masses, assuming that before the process of compression and extrusion begins they exist at a temperature more or less elevated above that at the surface of the earth. The locus of the rock flow might, therefore, be in deep regions several miles down, so deep indeed that relief of pressure could not occur by folding of upper layers or strata, which would involve the bodily uplift of rocks above, which rocks, exerting an enormous downward pressure may be of great relative rigidity.

The view of the origin of volcanic heat here advanced makes the paroxysmal nature of volcanic eruptions almost a necessity of the case. The rocks would resist an accumulation of pressure tending to cause them to flow, but finally, under continued increase of force, they would begin to readjust themselves. This would result in heating, softening and fusion. A vent might form and thus on account of the fluidity of the moving mass the accumulated pressure would for the time be relieved. But the original causes might still exist and continue, even after cooling of the heated material in the vents, to result in pressure accumulation, renewed flow and fresh outbreaks at periods more or less remote. The final decay of volcanic action in any region would result from such a permanent readjustment of strains as to entirely relieve the rock masses of any pressures which could become critical and cause flow.

During the cooling of a globe of heated and partly fused matter, such as the earth and moon are believed to have once been, the early volcanic outbursts on them would be without violence, and it seems likely that the materials ejected would have temperatures not greatly above that of the surrounding masses. An eruption at that time would be a welling up of great bodies of rather quiescent lava derived at once from the fluid contents below a but slightly cooled surface. As the further cooling made the body more solid and rigid, especially at the outside surface, the mechanical energy spent in causing an eruption would lead to higher temperatures of erupted matter, which would escape with more violence, explosions of vapor or gas would occur, partly due to vapors evolved from the melted masses upon relief of pressure at the vent, and partly the result of contact of the hot lavas with colder surrounding rocks containing gases or water. Ashes and cinders would become a feature of the eruption. At still later stages eruptions would become less frequent and vents less numerous, but the violence of the outbursts would increase, owing to the very high temperatures reached by the extruded matter during the journey toward expulsion.

It may seem somewhat paradoxical to hold that as a body, such as is the moon, cooled, the temperature of the ejected volcanic matter would rise, but in the present view this would be a consequence of the necessary exertion of greater pressures to cause eruption, owing to the enormous amount of mechanical work or energy expended, as the matter would be forced from greater depths. It happens that upon the earth much of the evidence of volcanic action in archaic or early geological times has been obliterated by erosion and sedimentation, but we have in the moon's surface a record which is not so modified or defaced.

From the whitish streaks surrounding such craters as Tycho Brahe and Copernicus, a type of crater not very numerous on the moon, which streaks are most conspicuous at the time of full moon, it is seen that there have been effects of eruptions of these great craters which extend over hundreds of miles from the craters. These whitish streaks are superimposed upon, and therefore later than, many of the other craters and markings over which they spread. These streaks are probably the depositions from condensed vapors which left the craters in almost radial lines. Inasmuch as the moon has very little atmosphere even at its lower surface and much less at the heights from which these vapors escaped in leaving the craters, the straight line or radial direction taken by them is not surprising; in fact, it is necessary. Vaporous matter escaping into a vacuum moves in precisely that way. Had the earth no atmosphere, the ashes and vapors from a volcanic crater would move away from it in just the same manner, and would be scattered in radial streaks from the notches in the crater walls and to enormous distances. If again the surface of the moon, as seems likely owing to absence of water, be covered with loose masses, or be broken instead of smooth, or be covered with pieces of rock of varying size, it is easy to understand why these whitish streaks should require for visibility a high angle of solar illumination. The condensed deposits would fall in between the boulders or stones on the surface and at low solar elevations would be in the shade or shadow of the broken pieces on the surface. That the surface of the moon, in large part, may be covered with fragments of rock, boulders and stones is probable from the great part that volcanic action has played in giving configuration to its surface, and the absence of any influences which would alter the aspect or general make-up of the surface outside of volcanic disturbances. The markings alluded to as existing around such craters as Tycho and Copernicus, as well as the great depth and other marked characteristics of these and similar craters, declare them to be the more recent of the great volcanic outbursts on the lunar surface. They bear the impress of having been very violent, and the vapors indicate ejections hot up to the point of vaporization. If the view presented is correct, this is entirely natural. On the other hand, contrast these craters with those called Archimedes and Plato, lava plains, surrounding which we see no vapor or fume streaks, and no evidence of great violence, and we are brought to infer that these latter are the results of more ancient action in the nature of more gentle welling up from below of fused matter, not so greatly heated by the energy of expulsion. Such craters are shallow and were probably more in the nature of quiescent pools or lakes of lava than great relief vents from great depths traversed by materials at high velocity and at the high temperatures brought about by the process of superheating while moving against resistance in volcanic pipes. So far then as the moon furnishes evidence on this subject it may well repay further study, and its condition seems to confirm the position taken herein. It has sometimes been claimed that much of the explosive effect of gas and steam from volcanoes may be due to water entering or percolating through heated strata and being converted into steam at enormous pressures. But the possibility of this is doubted. The very pressure of vapor would stop the process at its outset. No water would enter a hot stratum unless forced in by a pressure in excess of that which the steam would acquire upon its generation. A boiler cannot be fed with water by a pump which yields less pressure than that carried by the boiler itself.

If, however, the water be already present in a rock stratum which is invaded by hot lava rising in a volcanic fissure, then its conversion into steam and the violent emission thereof may readily take place.

It is conceivable too that considerable movement or shifting under pressure of any moist stratum over considerable distances, especially through a restricted channel, may result in heating it to a temperature sufficient to generate steam. Here again, as in the case of the rock flow before referred to, the work done in moving the particles against great resistance may under proper conditions cause an accumulation of heat energy sufficient to account for explosive effects when the material reaches a vent. Under such conditions also, the expulsion of hot mud or sand with steam may occur without the concurrence of lava flow.

The considerations herein put forward seem to furnish a basis for a dynamical theory of volcanoes. Doubtless the action of heating a flowing rock by energy expended upon it may be, and perhaps is, often supplemented by other causes, such as chemical action brought about by hot contact of substances having affinity for each other. Gaseous products under high pressures may be the consequence of the reactions. Limestone or other carbonate may be decomposed by the contact of hot lava, and carbonic acid gas in great volumes be thus liberated.

We certainly have no need of recourse to an assumption of the existence of large localized bodies and radium minerals to explain volcanic action. To say the least such an assumed store of this rare element is improbable.

The view here advanced, it is thought, presents far less difficulty. It is indeed an extension of Mallet's idea to include other factors of energy besides pressure.

The fact that the heated volcanic masses are in the earth, surrounded by materials of low heat-conducting power, makes the accumulation or retention of heat energy generated by mechanical work possible. The local character, as well as the varied nature of volcanic phenomena, is not difficult to understand. Volcanic outbursts must continue so long as readjustments of the positions of rock masses under a critical condition of pressure occur with the deeper surface layers.

If, as appears probable, the earth's interior is metallic iron, surmounted by a covering of oxidized lighter material, slag-like in character but altered by water and sedimentation, etc., the interior temperature or that of the metallic body is not likely to be very high, and it must be fairly uniform in spite of the gradual increase noted in the surface rocks at increasing depths. Such surface rocks or layers, being of relatively low heat conductivity, serve, so to speak, as a non-conducting blanket in which alone a considerable temperature gradient would be manifested. This con-

dition does not forbid the possibility of the readjustments of masses herein regarded as the initial cause of superheating, even if those masses be quite hot but under such gravitational pressure of superincumbent masses as to forbid fusion.

THE STRUCTURE OF METALS.*

By PROF. J. A. EWING.

IT will not be disputed that this is a primary concern of the engineer, who in all his problems of design is confronted by the limitations imposed on him by the strength and elasticity of the materials he employs. It is a leading aim with him to secure lightness and cheapness by giving to the parts such dimensions as are no larger than will secure safety, and hence it is of the first importance to know in each particular case how high a stress may be applied without risk of rupture or of permanent alteration in form. Again, the engineer recognizes the merit, for structural purposes, of plasticity as well as strength, and in many of his operations he makes direct use of that property, as in the drawing of wires and tubes or the flanging of plates. He is concerned, too, with the hardening effect that occurs in such processes when work is expended on permanently deforming a metal in the cold state, and also with the restoration to the normal condition of comparative softness which can be brought about by annealing. Nor can he afford to be indifferent to the phenomena of "fatigue" in metals, which manifest themselves when a piece is subjected to repeated alternations or variations of stress—fatigue of strength and fatigue of elasticity, which, like physiological fatigue, admits under some conditions of restcure, inasmuch as it tends to disappear with the lapse of time.

To engineers, quite as much as to physicists and chemists, we owe in recent years an immense extension of knowledge regarding the structure of metals. This had come about mainly by the intelligent use of the microscope.

We now know that this process of crystal growth occurs not only in the solidification of a metal from the liquid state, but in many cases during cooling through a "critical" temperature when the metal is already solid. We know also that the process may in certain conditions go on slowly at very moderate temperatures. We know also that the process of annealing is essentially the raising of the metal to a temperature at which recrystallization may take place, though the metal remains solid while this internal rearrangement of its particles goes on. Whether crystallization occurs in solidifying from the liquid or during the cooling of an already solid piece it results in the formation of an aggregate of grains, each one of which is a true crystal. Their size may be large or small—*in general*, quick cooling means that crystallization starts from many nuclei, and the resulting grains are consequently small; with very slow cooling you get a gross structure made up of grains of a much larger size.

It was shown by Mr. Rosenhain and myself that when a piece of metal is strained beyond its limit of elasticity, so that permanent set is produced, the yielding takes place by means of slips between one and another portion of each crystal grain. A part of each crystal slides over another part of the same crystal, as you might slide the cards in a pack. It is as if all the soldiers at one side of a given line were to take a step forward, those on the other side remaining as they were, or as if all the men in the front rows took a step to the left, while those in the rows behind kept their places. In other words, the plasticity which a metal possesses is due to the possibility of shear on certain planes in the crystal that are called "cleavage" or "gliding" planes. Plastic yielding is due to the occurrence of this shear; it may take place in three or more directions in a single grain, corresponding to the various possible planes of cleavage, and in each direction it may happen on few or many parallel planes, according to the extent of the strain to which the piece is subjected. Examine under the microscope the polished surface of a piece of metal which has been somewhat severely strained after polishing, and you find that the occurrence of this shear or slip is manifested on the polished surface by the appearance of little steps, which show themselves as lines or narrow bands when looked at from above. To these we gave the name of slip-bands. Just as the piece of metal is an aggregate of crystal grains, the change of shape which is imposed upon it in straining is an aggregate effect of the multitude of little slips which occur in the grains of which it is made up. Each grain, of course, alters its form in the process.

Further, in the process of straining we have, first, an elastic stage, extending through very small movements, in which there is no dissipation of energy and no permanent set. When this is exceeded, the slip occurs suddenly; the work done in straining is dissipated; if the straining force is removed a strain persists, forming a permanent "set"; if it continues to act it goes on (within certain limits) producing augmented strain. In general, a large amount of strain may take place without the cohesion between the gliding surfaces being destroyed. Immediately after the strain has occurred there is marked fatigue, showing itself in a loss of perfect elasticity; but this will disappear with the lapse of time, and the piece will then be harder than at first. If, on the other hand, a process of alternate straining back and forth be many times repeated, the piece breaks.

* Paper read before the Engineering Section of the British Association for the Advancement of Science.

These are now familiar facts. Can we attempt to explain them on the basis of a molecular theory which will at the same time offer a clue to the process of crystal-building as we find it in metals? Just as in dealing with magnetic phenomena, I take as startingpoint the idea that the stability of the structure is due to mutual forces exerted on one another by its elementary parts or molecules, and that the clue to the phenomena is to be sought in the play of these mutual forces when displacement of the molecules occurs.

At first, when the displacement by sliding is exceedingly small, the strain is a purely elastic one. The molecules adjacent to the plane of sliding pull one another round a little, but without breaking bonds, and if in this stage the strain is removed, by letting the plate slide back to its original position, there is no dissipation of energy. The work done in displacing the molecules is recovered in the return movement. We have here a representation of what happens between each pair of adjoining rows in the elastic straining of a metal. So far the action is within the limit of elasticity; it leaves no permanent effect; it is completely reversible.

But now let the process of straining be carried further. The opposing molecules try to preserve their rows intact, but a stage is reached when their resistance is overcome; the bonds are broken, and they swing back, unable to exert further opposition to the slip. The limit of elasticity has now been passed. Energy is dissipated; set has been produced; the action is now no longer reversible. The model shows well the general disturbance that is set up in molecules adjoining the plane of slip, which we may take to account for the work that is expended in a metal in producing plastic strain.

Moreover, when the slip on any plane stops and the molecules settle down again, the chances are much against their all taking up the normal orientation which they had before the disturbance. What I have called dissenting groups or unstable coteries are formed as a result of the disturbance. Here and there like poles are found in juxtaposition. Viewed as a whole, the molecular constitution of the metal in the region adjacent to the plane of slip is now uncertain and patchy. It includes parts whose stability is much less than normal. Individual molecules or small groups in it are very feebly stable; a touch would make them tumble into positions of greater stability.

Observe how all this agrees with what we know about the nature of plastic strain through experiments on iron or other metals. Its beginning is characteristically jerky. Once the critical force is reached, which is enough to start it, there is a big yield, which will not be stopped even by reducing the amount of the straining force.

Again, we know that there is an action that continues after the straining force has done its main work. I ascribe this to the gradual breaking up of the more unstable groups which have been formed during the subsidence of disturbance in the earlier stage of the slip.

Further, we know that overstrained iron is very imperfectly elastic until it has had a long rest, or until it has been raised for a short time to a temperature such as that of boiling water. This is to be expected when we recognize the presence of unstable individuals or groups resulting from the overstrain. When the elasticity of the overstrained piece is tested by removing and reapplying the load, some of these tumble into new positions, making inversible movements, which dissipate energy and produce hysteresis in the relation of the strain to the stress, although the strain is quasi-elastic. At ordinary temperatures these unstable groups are gradually becoming resolved, no doubt through the action of the molecular movements that are associated with heat, and hence the slow progressive recovery of perfect, or nearly perfect, elasticity shown by the experiments of Muir. Let the temperature be raised, and they disappear much more quickly. In warm surroundings the rest-cure for elastic fatigue does not need to be nearly so long.

Rosenhain has recently shown that after the slipbands on the surface of an overstrained specimen have been obliterated by polishing, traces of them will reappear on etching if only a short interval of time is allowed to elapse since the over-straining; but if time is given for complete recovery no traces are found. This is in remarkable agreement with the view now put forward, that the layers contiguous to the surface of slip contain, for a time, comparatively unstable groups. They are consequently different from the normal metal until the unstable groups are resolved, and the temporary difference manifests itself on etching, provided that is done while the difference still exists.

From the engineer's point of view a much more important matter than this fatigue of elasticity is the fatigue of strength that causes fracture when a straining action is very frequently repeated. Experiments which I made with Mr. Humfrey showed that this action begins with nothing more or less than slight slip on surfaces where the strain is locally sufficient to exceed the limit of elasticity. An alternating stress, which makes the surfaces slip backward and forward many thousands or it may be millions of times alternately, produces an effect which is seen on the polished surface as a development of the slip lines into actual cracks, and this soon leads to rupture.

We have, therefore, to look for an effect equivalent to an interruption of continuity across part or the whole of surface of slip, an effect progressive in its character, becoming important after a few rubbings to and fro if the movement is violent, but only after a great many rubbings if the movement is slight.

That there is a progressive action which spreads more or less into the substance of the grain on each side of the original surface of slip was clearly seen in the experiments referred to. It was found that a slipband visible on the polished surface of the piece broadened out from a sharply defined line into a comparatively wide band with hazy edges, and this was traced to an actual heaping up of material on each side of the step which constituted the original line.

I think this suggests that under alternating stresses which cause repeated backward and forward slips, these do not occur strictly on the same surface in the successive repetitions, and hence the disturbance spreads to some extent laterally. It may be conjectured that slip on any surface leaves a more or less defective alignment of the molecular centers; that is to say, the rows on one side of the plane of slip cease to lie strictly in line with those on the other side. If this occurs over neighboring surfaces, as the result of slips or a number of parallel planes very close together, the metal throughout the affected region loses its strictly crystalline character, and with it loses the cohesion which is due to strict alignment.

Taking a previously untrained piece, it is clear that the facility with which slip will occur at any particular surface of slip in any particular grain depends not only on the nature of the metal and on the orientation of the surface in question to the direction of the stress, but also on the amount of support the grain receives from its neighbors in resisting slip there.

ACTION OF RADIUM EMANATION ON THE HUMAN BODY.

SOME interesting experiments have been recently carried out by S. Loewenthal,* to ascertain whether the human body, either in a healthy or morbid condition, would undergo any appreciable constant reaction under the influence of small amounts of radium emanation. Water from the mains served as the vehicle for the emanation. One gramme of radium-barium carbonate, containing 0.3 milligramme of radium bromide, was wrapped with parchment in a small glass bottle and introduced into a larger glass vessel containing one-quarter of a liter of water from the mains, the bottle being sealed air-tight. The actual amount of emanation was determined by means of the Elster-Geitel electroscope.

Tests of the water containing the emanation showed an average fall of 1,000 to 1,500 volts per hour for each cubic centimeter, according as the consumption was more or less rapid.

Given amounts of this liquid were supplied to the person experimented on, in different ways. In order to ascertain the admissible maximum amount exerting no noxious action in the case of healthy people, the author based his conclusions on the fact that the bodies of those who are in the habit of working with radium will accumulate considerable amounts of emanation, which may be ascertained in the expired air and excreta. By experiments made on himself, he stated that a minimum of 10,000 units = 10 cubic centimeters of emanation water had to be incorporated with the body in order to be detected.

No disturbance, subjective or objective, was stated as a consequence of the experiments, either in the case of the author himself or with other persons. Nor could any such disturbance be observed with rabbits or cats which had been treated with the emanation water.

Quite different were the results obtained in the case of sick people. Owing to the specific effects exerted by thermal sources on certain chronic diseases of the articulations, etc., the author began experimenting on patients suffering from rheumatism of the articulations, only such cases being investigated in which a stationary conditon had been established for some time past.

In each of the eleven cases examined by Loewenthal, the pains in the parts formerly affected would augment either on the day of incorporating 10,000 units or on the day following this absorption. This constant reaction strikingly recalls the bath reaction observed in hot-spring health resorts and generally considered as a favorable indication preceding recovery. The similarity of the two reactions becomes still more striking when the emanation water is added to ordinary baths. The emanation is found to be mainly absorbed by the lungs.

Assuming the earth to be in thermal equilibrium, then, even if the whole of this interior heat be due to radium alone, the mean quantity per cubic centimeter cannot much exceed 1.75×10^{-13} grammes. The conclusions of Rutherford, based on somewhat different values for the constants involved, give an equivalent of 1.52×10^{-13}. Now Strutt has found that the poorest igneous rock examined by him, namely, Greenland basalt, contains more than ten times this quantity, and an average rock fifty or sixty times the amount. The assumption that the earth is cooling only aggravates the difficulty, and facts appear to tell against the theory that it is getting hotter. Also, we must take into consideration the heat due to the existence of uranium, thorium, etc. We appear, therefore, to be driven to one of two assumptions: either (*a*) that the rate of heat production by radium diminishes as we approach the center of the earth; or (*b*) that the interior of the earth differs markedly in constitution from the exterior crust.

* Physikalische Zeitschrift, No. 16, 1906.

[Continued from SUPPLEMENT No. 1603, page 25681.]

THE MODERN MANUFACTURE OF ALCOHOL.—II.*

THE COMMERCIAL PRODUCTION OF ALCOHOL.

THE manufacture of alcohol may be divided into three parts: the preparation of the fermentable saccharine liquid called must or wort, fermentation, and

FIG. 12.—SUGAR BEET. (ALL SUGAR BEETS ARE LONG AND POINTED.)

extraction of alcohol from the fermented must. Fifty years ago wine, cider, and other fermented fruit juices were almost the only sources of alcohol known in France. Afterward the wine crop was so greatly diminished by the ravages of the phylloxera and the oidium that the distillation of wine practically ceased. It is now carried on chiefly for the production of fine brandies and by the *bouilleurs de cru*, or farmer-distillers, who are permitted to make untaxed spirit from their own fruit for their own use.

Distillers of alcohol have consequently been forced to other and less facile sources than wine.

I. Preparation of the Must.

From Beets.—Beets were introduced into France in the sixteenth century. In 1799 the German Achard first succeeded in extracting from them sugar equal to that obtained from cane. Sugar beets contain about 10 per cent of sugar and other sources of alcohol which are extracted by various methods. The oldest method is by grating and pressing. The beets are washed in a revolving drum and grated by machine. A 2-horse-power grater produces about 5 tons of pulp per day. The juice, extracted from this pulp by a hydraulic press, is strained and acidified with 1-400 of its weight of sulphuric acid, or twice as much hydrochloric acid in order to facilitate the transformation of the saccharose into invert-sugar and to prevent injurious secondary fermentations. The juice, or must, is then ready for fermentation.

In large establishments the press is not used, the must being obtained by infusion. The beets are sliced and soaked in acidulated water in 25 gallon tubs, each of which is charged with 100 pounds of beets. By a series of pipes and valves the tubs can be connected, as desired, with a water tank, a reservoir of compressed air, the receiving vats for wort, and with each other.

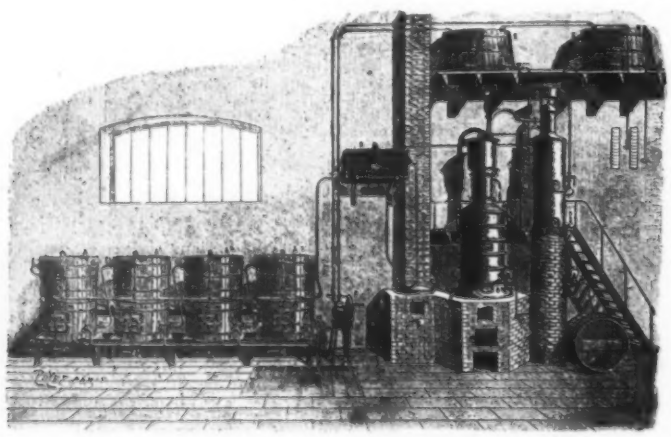


FIG. 13.—INFUSION VATS. AT THE RIGHT DISTILLING AND RECTIFYING TOWERS.

Each tub may be operated independently or the wort may flow through the entire series, beginning with nearly exhausted roots and ending with fresh ones, thus acquiring great strength and yet leaving no sugar unextracted. Cold infusion, which was formerly practised, has been almost entirely replaced by hot infusion.

In another process the sliced beets are cooked by steam, in open vessels or under pressure, mashed, and mixed with an equal volume of water or "vinasse" (fermented wort from which the alcohol has been distilled), and one or two thousandths of their weight of sulphuric acid.

From Beet Molasses.—Beet molasses, a by-product of the sugar manufacture, contains 48 per cent of sucrose and 1 per cent of glucose, but it does not yield a good wort on simple dilution because it also contains alkalies, nitrates, and other salts, and empyreumatic organic substances which interfere with the alcoholic fermentation, as well as other substances and germs which provoke injurious subsidiary fermentations. These difficulties are obviated by adding water and acid, and by boiling.

From Jerusalem Artichokes, etc.—The Jerusalem artichoke is a plant which resists drought and frost and grows well in poor soil, thriving in localities where neither the potato nor the sugar beet produces a paying crop. The yield of tubers is about 12 tons per acre. The tubers contain 15 per cent of fermentable sugar and 2 per cent of inuline, a variety of starch which is converted into levulose by simple boiling with water. Wort is made from them by the methods used for beets.

Various tubers, the stalks of maize and sorghum, and other vegetable substances which contain sugar ready formed are treated by similar methods.

From Grain.—The grains commonly used by the distiller are maize, rye, barley, oats, wheat, and rice. Of these, maize is the most important. The percentages of saccharifiable matter are:

	Starch.	Dextrine.
Maize	67	5
Wheat	60	6
Barley	54	5
Rye	56	5
Oats	47	4
Rice	89	1

The transformation into sugar is effected either by the diastase of malt or by acids.

Malt is the result of the germination of barley or other grain. Barley malt is used chiefly by the brewer, maize malt by the distiller of alcohol. The grain is first soaked for 40 or 50 hours in water at about 78 deg. F., and then spread to a depth of 10 to 20 inches

FIG. 14.—JERUSALEM ARTICHOKE.

on the floor of the malting house to sprout. In about 10 days when the young shoot has attained three or four times the length of the grain and has begun to turn yellow, the operation is stopped by the removal of the shoot by machines. The removal must be performed carefully and thoroughly as the fatty matters which are accumulated in the shoot, if left in the malt, would interfere with subsequent operations and impair the flavor of the spirits produced. The sprouted grains, deprived of their sprouts, contain diastase and constitute malt, which is used both fresh and after being dried in the open air or in rooms heated to about 120 deg. F.

Fresh or green malt is stronger and hence more economical than dry malt, but it must be used at once. Dry malt keeps very well, but is less active than fresh malt, as some of its diastase has been destroyed in the drying process. Before being mixed with malt the harder grains are boiled until they form a gruel. The soft grains, rye, wheat, and oats, are ground into meal which is moistened, mixed with one-fourth or one-fifth of its weight of ground barley malt and heated to from 130 deg. to 150 deg. F. A higher temperature accelerates the process of saccharification, but diminishes the yield of sugar. Experience has shown that a mixture

FIG. 15.—BARLEY. VARIETY, ALBERT.

of different grains gives the best result. In practice the process is arrested before all of the diastase of the malt has been consumed, and while some of the carbohydrates of the grain remain in the form of dextrine, the conversion of which into sugar goes on during the subsequent fermentation.

Various methods of malting are employed in different countries. Both time and money are saved by substituting acids for malt. The acid process is applied to damaged wheat, to rye and rice, and especially to maize. The acid commonly used is sulphuric or hydrochloric, or gaseous sulphurous acid under pressure. The operation is conducted in a thick-walled copper tank, holding 400 gallons, with a perforated double bottom, which is charged with 600 or 700 pounds of crushed maize. One hundred and sixty gallons of water and 35 pounds of hydrochloric acid are added and steam at a pressure of three atmospheres is applied for 50 minutes. The saccharine wort thus produced is diluted and neutralized with chalk or lime. This apparatus may be charged and discharged twenty-two times in twenty-four hours. The acid process can also be conducted at the atmospheric pressure in open vessels.

From Potatoes.—Potato alcohol is produced most abundantly in Germany and Austria. The potatoes are washed and placed in a boiler where they are heated with steam at a pressure of three atmospheres for two

FIG. 16.—MAIZE LARGE YELLOW.

hours. As potatoes contain 70 per cent of water, no water need be added, and they leave the boiler in the form of paste. This is forced through a machine which makes it perfectly smooth and homogeneous. It is then cooled to about 160 deg. F. and mixed with malt in tubs, which sometimes contain stirring and cooling apparatus. Boilers of 1,300 gallons and malting

* Specially translated from "Sa Majesté l'Alcool," by L. Baudry de Saunier, for the SCIENTIFIC AMERICAN SUPPLEMENT.

vats of from 3,000 to 5,000 gallons capacity are employed in the largest establishments. In the acid process the potatoes are mixed with 5.5 per cent of hydrochloric acid, by weight, and treated with steam at a pressure of three atmospheres until a sample of the mass no longer turns blue when mixed with a solution of iodine. The boiler is then emptied and the paste is cooled and neutralized with chalk.

Similar methods are used in the preparation of wort from other starchy materials, such as sweet potatoes, acorns, chestnuts, carrots, peas, manioc, chicory, dandelion, etc.

From Cellulose.—The cellulose of wood, sawdust, rags, cotton waste, paper, straw, leaves, turf, etc., also yields a fermentable saccharine wort when treated with acids. Braconnot, who first studied the transformation of cellulose into sugar, found that clean rags and paper yield their own weight of sugar when treated with seven times their weight of sulphuric acid. Sulphurous acid and a pressure of seven atmospheres are used in the Classen process, which is applied in the United States to sawdust and sawmill refuse. The phenomena of the transformation closely resemble those of the saccharification of grain and potatoes by acids.

Fermentation of the Wort.

The distiller used to purchase from the brewer the yeast required for the fermentation of the wort obtained from the sources enumerated above, but distillers now cultivate their own yeast and make their own leaven, selecting the breeds or cultures of yeast which have been found best adapted to the special objects of the manufacture. The preparation of the leaven is a matter of considerable importance, for on

FIG. 17.—SORGHUM.

it depend both the quantity and the quality of spirits produced.

Yeast is simply the aggregate of the yeast cells. Leaven, to quote Brunet's treatise on the subject, is "a medium in which yeast can multiply and become established." It may consist of a portion of the wort and, in any case, it is a thin paste or viscous liquid, composed of materials rich in albumen and gluten, in which the yeast acquires such strength that when it is diffused through the entire body of the wort, it develops its maximum activity at once. Two weeks are occupied in the preparation of good distillery leaven. The leaven is made in special rooms which are kept as aseptic as possible. The walls are non-porous, the floors cemented and slightly inclined. The temperature is maintained between 59 deg. and 64 deg. F., winter and summer, and abundant light and ventilation are provided. In short, every precaution is taken against the development of mold and injurious germs.

The fermenting vats, of oak or pine, varnished or coated with paraffine, hold from 400 to 1,400 gallons each. Some large distilleries have vats of 10,000 gallons' capacity. The vats are cleaned successively with alkalies, acids, and antiseptic solutions (bisulphite of lime, etc.).

In these vats the wort, cooled to from 60 deg. to 68 deg. F., is mixed with 10 per cent of leaven. Worts are classified as thin or light, and thick or heavy. Light wort (10 degrees of the saccharimeter) is the result of the old process of saccharification in open vessels. Heavy wort (20 to 24 degrees) is made by boiling under pressure. The distiller prefers heavy wort, although it requires more leaven, because it ferments with greater certainty and regularity and costs less for plant, fuel, and labor.

As the fermenting wort foams considerably the vats are not completely filled. The fermentation continues three days. Toward the end of the operation it is necessary to cool heavy wort and add water, in order to prevent the temperature exceeding 90 deg. F. or the

FIG. 18.—POTATO GROWN FOR DISTILLING. VARIETY LA GÉANTE.

alcoholic strength becoming sufficient to arrest the fermentation before all the sugar has been decomposed.

As soon as the fermentation is completed, the liquid, which is now known as wash, is thoroughly cooled and dosed with a little antiseptic (1-10 per cent to 2 per cent of ammonium fluoride) to prevent any possible secondary fermentation.

Special Processes.—Distillers of grain and potato spirit are beginning to employ two new processes of simultaneous saccharification and fermentation.

The "amylo process" is the result of the study made in 1892 by Dr. Calmette, director of the Pasteur Institute at Lille, of the Chinese yeast used in the manufacture of chum-chum, or rice-brandy. Dr. Calmette succeeded in isolating the active organism, a mold to which he gave the name *Amylomyces Rouxii* (Fig. 3). In 1897 Boidin and Rolants proved that a practical leaven of remarkable properties could be made of this mold and "vinasse" (light wash exhausted by distillation). These experiments led to Collette and Boidin's amylo process, which not only effects saccharification and fermentation in one operation, but also permits the use of sterilized wort and thus insures the absence of secondary fermentations.

In the ordinary process of malting the starch is changed partly into glucose and partly into dextrine by the diastase of the malt, the proportion of dextrine being increased by a high temperature of malting. The conversion of this dextrine into glucose, and then into alcohol, is accomplished in the fermenting vat, under the combined influences of the yeast and the diastase which the wort still contains. Hence the wort cannot be sterilized by boiling, which would destroy the diastase. Sterilization with salicylic acid, formic aldehyde, bisulphide of carbon, and other antiseptics has been tried, but with uncertain result. The amylo process removes this difficulty, but it is applicable only to light worts, yielding less than 5 per cent of alcohol. For heavy worts, which yield 8 or 9 per cent of alcohol, Collette and Boidin replace the *Amylomyces Rouxii* by a Japanese mold, which they have named *Mucor beta* (Fig. 4). This produces less acid than the Chinese mold, the action of which is ultimately

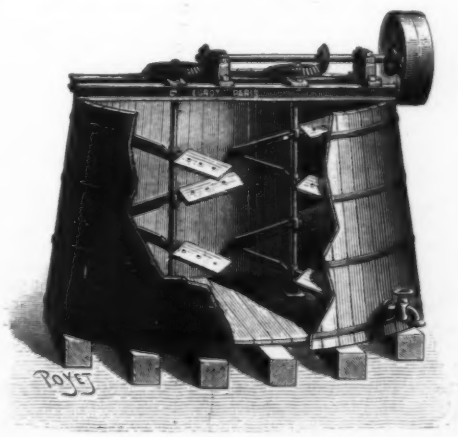


FIG. 19.—MASH TUB FOR POTATOES.

arrested by its own secretions. Both of these molds are used in anaerobic conditions, for when exposed freely to the air they oxidize the carbohydrates completely into carbonic acid and water.

The potatoes or grains are first subjected for three hours to the action of steam at three atmospheres. After the mass has cooled to 158 deg. F. a little malt (1 or 2 per cent) is added in order to liquefy it, an operation which occupies one hour. The fluid mass is then sterilized for 20 minutes by steam at 248 deg. F. and conducted to air-tight vessels of 25,000 gallons capacity where, after being exactly neutralized, it is cooled to 100 deg. F. and the leaven is added by a rigorously aseptic manipulation. The leaven consists of only 2.5 ounces of a pure culture of the Chinese or Japanese mold on boiled rice, diluted with an equal or greater quantity of the sterilized wort. This is mixed with the contents of the great vat by a mechanical stirrer or a jet of sterilized air. In twenty-four hours the entire mass is permeated with filaments of mycelium and saccharification is complete.

Then the alcoholic fermentation commences under the influence of the enzymes secreted by the mold, but as enzyme fermentation is slow, it is accelerated by adding, aseptically, a pint of pure yeast, after the contents of the vat have been cooled to 91 or 92 deg. F. Under the combined action of the mold and the yeast the alcoholic fermentation is completed and the wash is ready for distillation in about 100 hours. The carbonic acid produced in this fermentation in closed vessels is compressed in steel cylinders and sold to manufacturers of carbonated water, etc.

Dr. Calmette, with an unselfishness rare even among men of science, gave the sum (250,000 francs or nearly $50,000) which he received for his rights in the process to the Pasteur Institute at Lille.

The amylo process, however, has a rival in the Effront process of combined saccharification and fermentation with common yeast (*Saccharomyces*) which has been made immune, by cultivation and selection, to the effect of antiseptics. Dr. Effront, of the University of Brussels, discovered that one part of hydrofluoric acid or a fluoride prevents secondary fermentations in from 400,000 to 1,000,000 parts of wort, without impairing the stock-feeding value of the distillery waste. On the other hand, by means of successive cultures with in-

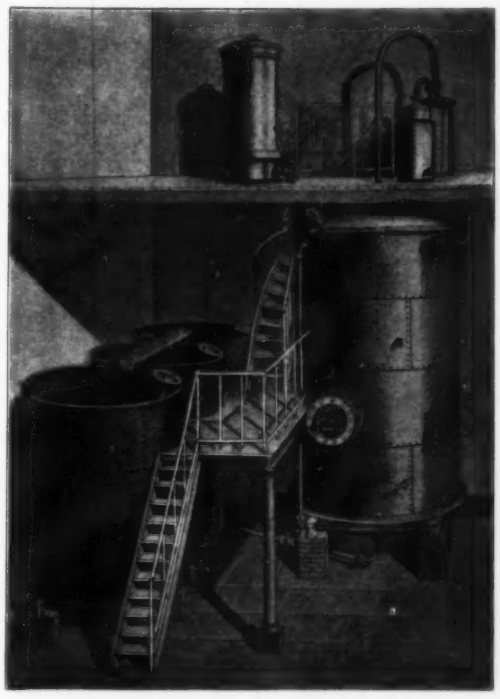


FIG. 20.—APPARATUS FOR CONTINUOUS ASEPTIC FERMENTATION.

creasing doses of hydrofluoric acid, he obtained yeast which worked normally in wort containing 1-1,000 of its weight of the antiseptic.

Wort so treated destroys all non-immunized germs that may find their way into it, while the immunized yeast flourishes and, owing to its secretion of diastatic enzymes, at once converts glucose into alcohol and forms glucose from other carbohydrates. The yeast can be kept in open vessels. One distillery which uses this process has not renewed its yeast in three years.

(To be continued.)

DYEING OF ANIMAL AND VEGETABLE FIBERS WITH HYDROGEN PEROXIDE.

DR. MANN, of Munich, has recently introduced a process augmenting the value of certain aniline colors by increasing their power of resistance to alkalies, light, chloride of lime, and mineral acids. When animal and vegetable fibers are dyed with different derivatives of benzol and naphthaline, the process is as follows: The organic substances are dissolved in water or in acetic acid, a solution of a metallic salt, and a determined quantity of hydrogen peroxide (oxygenated water), one molecule for one molecule of aniline. If mineral acids are used for the solution, or salts of mineral acids from organic matter, or if the solution of oxygenated water contains a free mineral acid, the latter, or the acid which becomes free during the operation, must be fixed by the addition of acetates, oxalates, and tartrates. The solution prepared for dyeing must not color a solution of potassium chrome blue.

The colors obtained vary from light brown to dark brown and gray, and if the quantities of the oxidizing agent, the metallic salt, and the organic bodies are

regulated, various other shades can be obtained. When aniline or copper salts are used at the ordinary temperature, an olive-green results.

Oxygenated water may be replaced, without detriment, with ozone, hypochlorites, chlorine water, permanganate, and other similar oxidizing agents. With the exception of alkaline and earthy alkaline salts, all metallic salts can be used. Those which are themselves strongly colored are particularly suitable as, for instance, the salts of iron, copper, chromium, nickel, and cobalt; but the salts of manganese, platinum, vanadium, and cerium will answer. All the organic bodies derived from benzol or naphthaline can be employed.

For proportions, one part of weighted organic substance, metallic salt of equal weight, and oxidizing substance corresponding to one molecule of the organic body are to be taken; for instance, one kilogramme of aniline, one kilogramme of ferric chloride, and 365 grammes of oxygenated water. The quantity of water and of fiber depends on the shade desired. The dyeing bath is heated to a temperature exceeding 80 deg. C. The fiber is manipulated by machinery for a time, and then it is mechanically freed from the coloring matter adhering to it and dried.

It makes no difference whether the metallic salt is added to the bath, or the fiber saturated with it.

We give three formulas, showing the inexpensiveness of the process.

1. Light Brown Color.—Take one kilogramme of aniline or 1,387 grammes of chlorhydrate of aniline, 1,500 grammes of sodium acetate, 365 grammes of oxygenated water, 1 kilogramme of ferric chloride, 50 kilogrammes of fiber, and 1,100 liters of water.

2. Dark Brown.—Take two kilogrammes of aniline, 730 grammes of oxygenated water, 2 kilogrammes of ferric chloride, 10 kilogrammes of fiber and 1,500 kilogrammes of water.

3. Gray.—Take 2 kilogrammes of carbonic acid, 730 grammes of oxygenated water, 2 kilogrammes of ferric chloride, 10 kilogrammes of fiber, and 1,500 kilogrammes of water.—Translated for SCIENTIFIC AMERICAN SUPPLEMENT from the Deutsche Färber Zeitung.

[Concluded from SUPPLEMENT No. 1606, page 25679.]

LARGE ELECTRIC AND STEAM LOCOMOTIVES.*

IN mountain helper service locomotives are frequently required to remain at work for extraordinary periods between fire cleanings, and during such intervals with the forcing of fires to the maximum, doing short service and pushing trains up the grade, together with drifting down grade, and long time between trips, there is considerable opportunity for variation in the temperature in the firebox and flues, which would tend to cause leakage and failure. Under such conditions, however, No. 2400 has been able to meet the requirements, and at the same time make use of an ordinary grade of run-of-mine 20 to 40 per cent volatile bituminous coal, and maintain ample boiler pressure at all times to handle the work.

The general condition of the machinery and boiler on January 6, 1906, after twelve months' service, was as follows:

Treads of tires show even wear amounting to 3-16 inch, or about 1-64 inch per month; tires calipered uniform in diameter.

High and low pressure cylinders were in good condition, being worn smooth and not oblong or bell-mouth.

The high pressure piston and low pressure slide valves were in good condition. Piston valves have had the packing rings renewed once and the slide valves have received no repairs.

The engine frames, splice bolts, keys, pedestal-caps, braces, etc., have given no trouble, and there have been no renewals nor repairs.

All driving bearings were in good condition, and while there have been two warm journals, due to lack of lubrication, since the locomotive has been in service, none of the frictional surfaces were injured.

The driving boxes were in good condition, crown brasses have given no evidence of becoming loose in the boxes, and are of sufficient thickness to continue in service for twelve months before renewals need be considered.

The driving wheels were fitted up when new with 1-16 inch end play between each hub and box, which has been increased to from 3-32 inch to ⅛ inch, the front and rear driving wheels on both high and low pressure engines having the greater amount.

All parts of the Walschaert gear were in good condition, and the total lost motion between the main driving wheel axles and the piston and slide valves, as measured at the valve stems, with the reverse bar in full forward position, averaged 3-64 inch for the low pressure and slightly less for the high pressure engines and for all engines in full back-up gear.

The boiler, which carries a working pressure of 235 pounds indicated, was in good condition, and there has been no evidence of weakness or any trouble due to staying, leaky seams, leaky or broken staybolts or leaky rivets. The staybolts are of the ordinary straight type, 1 inch in diameter, spaced by 3⅜ inch, with telltale holes drilled at the outer end.

The firebox was in good condition, and there has been no indication of leakage, except at the furnace door ring, where two defective rivets were replaced by countersunk head patch bolts.

The boiler tubes were good for another month's service, and there was but one flue plugged, which was due to its collapsing about eight feet from the front tube sheet.

This locomotive will remain in service until the latter part of January, 1906, when it will be removed on account of the tire wear having reached the limit allowable of ¼ inch at the tread; it will then have the driving wheel tires reset, boiler tubes removed, boiler cleaned out, boiler tubes repieced and reset, and whatever repairs that may be necessary given to the machinery, and repainted. It is estimated that the cost to make these repairs and put the locomotive in condition for another year's service, or 40,000 miles run, will be about $750 for labor and $250 for material, or a total of $1,000. (Note.—The approximate cost for the above repairs, which have since been completed, amounted to $759 for labor and $366 for material, or a total of $1,125.)

From the performance up to the present date it has been found that the following features embodied in the design of this locomotive have given entirely satisfactory results, with respect to design, maintenance and operation:

The flexible joints to the high and low pressure cylinder, receiver and exhaust pipes; articulated frame; intercepting, reducing and emergency valve and intermediate chamber system of compounding and simpling; combination hand and power reversing gear; Walschaert valve motion; high pressure piston and low pressure double ported slide valves; high and low pressure cylinder packing; method of securing high pressure cylinders to boiler; single disk main throttle valve; driver, crank pin and other bearings; injectors and water works; lubrication of valves, cylinders and bearings; tracking and riding qualities, going forward or backward around maximum curvature, and when pushing, pulling or braking trains or running light.

There has been no trouble on account of priming, and the results accomplished through the distribution of the work over four instead of two main crank pins and auxiliary parts have been markedly satisfactory.

In consideration of the boiler having 72.2 sq. ft. of grate area, 220 sq. ft. of firebox heating surface, 5,380 sq. ft. tube heating surface, and flat and radial sheet staybolts of the ordinary solid type, the performance of the boiler, fire-box, boiler tubes and stays, with 235 pounds indicated working pressure, has demonstrated that it is economical and entirely practicable to operate well-designed and constructed locomotive types of boiler under severe weather, water, fuel and handling conditions, with from 200 to 250 pounds boiler pressure.

While the boiler tubes are 2¼ inches in diameter and 21 feet in length, there has, with ordinary attention, been practically no difficulty on account of leaky or stopped-up boiler tubes, and the steaming has been at all times free, and such as would enable the locomotive to develop the maximum tractive power under the most severe operating conditions.

There was initially some irregular wear of the flange to the left front driving wheel tire of the forward engine, on account of the cross-equalizer of the spring gear not being sufficiently strong to carry the weight, but after a new equalizer was applied this trouble was eliminated. Several of the driving springs also broke, and the grate gear was redesigned to provide larger drop grate openings.

It also required some experimenting to make a suitable flexible connection between the oil delivery pipe and the low pressure cylinder steam chest, which, however, has resulted satisfactorily.

While it has been noted that quite a number of changes in minor details would be desirable, should other locomotives of this type be constructed, still, when taken as a whole, the design, construction and operation in general can be considered as efficient and economical.

From a transportation standpoint, locomotive No. 2400 has been performing the service of two standard consolidation locomotives, when used as a helper, and when handling through freight trains.

This results in a saving of delay which would produce overtime in many cases, from the fact that a heavy train might have to be held for the second consolidation locomotive helper, whereas No. 2400 takes the place of the second helper and moves the train promptly.

In startiing trains it has been frequently noticed that during unfavorable freezing weather conditions, with ice on the rails, No. 2400 would push the train and take the slack between the tender and engine of the pulling locomotive, before the latter had moved its driving wheels. It has also demonstrated that it has as great a hauling capacity when backing up as when going ahead; and for the reason that it has seemingly not been stalled since in regular service, it may not be out of place to mention here that it has been nicknamed "Maud," in comparison with the renowned mule that moves anything it goes up against.

The following are some of the results that can be obtained from this compound cylinder articulated type of freight locomotive, which cannot be duplicated by other single units of steam, electric or internal combustion locomotives now in use on American railroads:

1. A tractive power of about 84,000 pounds for starting heavy trains and for a speed of five miles per hour; and of 74,000 pounds at a speed of 10 miles per hour, placed under the control of one engineer and one fireman.

2. A self-contained machine generating the power necessary to develop its hauling capacity. With electric locomotives, where the source of power is separate from the machine which develops the hauling capacity, the first cost of the locomotive alone is, at present, about 50 per cent greater per pound of tractive power developed under working load than for steam locomotives of the 2400 type. To this must be added the greater cost for repairs and operation per mile run for the electric locomotive, and the installation, maintenance and operation of a current-producing conveying, storage, converting and distributing system, which would not be required by either a steam or an internal combustion locomotive, and all of which increase the capital and operating expenses very materially.

3. A total locomotive weight utilized for the development of tractive power in connection with a running gear, which makes the locomotive suitable for either hauling, pushing, or braking freight trains containing the maximum paying load per foot of track space, over level or mountainous railroads of maximum curvature.

4. A maximum tractive power with a minimum rail pressure per driving wheel, on account of the total weight of 334,500 pounds being distributed over 12 drivers, and a 30 feet 6 inches total, with a 10 feet rigid wheel base, resulting in minimum wear and tear on bridges, rails, ties and roadway. With electric locomotives the excessive weight concentrated on a short rigid driving wheel base and below the springs, together with the extremely low center of gravity, results in extraordinary rail pressures, thrusts and wear.

5. The elimination of retarded movement and stalling of trains on account of the usual slipping of driving wheels, as in the case of ordinary simple or compound cylinder steam locomotives, or with electric locomotives where the driving wheels are uncoupled and the current is naturally transmitted to the point of least resistance, which is the slipping wheels, resulting in no increase of power at the dead wheels. A higher tractive power is obtained to the weight per axle than with the ordinary steam locomotive, as the slipping due to the accumulation of high unbalanced pressure at the points of wheel and rail contact, does not occur at the same time in both engines. When one engine commences to slip a reduction in mean effective pressure follows, and it regains its grip on the rail without making it necessary to shut off or throttle the steam supply. The other engine, meantime, has been gaining power, thus preventing any appreciable loss of speed and consequent stalling of the train at a critical moment. These conditions are the same whether the slipping occurs with either the high or the low pressure engine, and the most frequent cause for stalling with electric or simple cylinder locomotives is thus overcome.

6. A tonnage and speed per train that will provide for the least number of locomotives and crews under the control of which the movement of the business is placed. This will result in the balancing of the power and movement of the maximum number of loaded and empty cars per hour over a single piece of track, with the proper degree of safety.

7. A minimum capital, repair, fuel, engine and train crew, oil, supply and dispatchment, cost per locomotive, train, car or ton mile.

8. A maximum retarding effect for the safe handling of heavy trains down steep grades at the highest speed permissible for a proper degree of safety.

9. A uniform turning moment to overcome journal friction of axles; rolling and flange friction of wheels; wave resistance of rail; atmospheric friction at ends and sides of rolling stock and inertia of train at time of starting, which will insure the minimum draft gear, machinery and boiler stresses, and reduce the tire and rail wear.

10. A subdivision of power and balancing, resulting in the minimum strains on the locomotive and track, and a reduced liability for wear, breakage or accident. Broken driving wheel axles on electric locomotives indicate that the more uniform torque does not eliminate the liability for such failures under normal conditions.

11. The minimum amount of dead weight and non-paying load, and the smallest number of bearings and parts per unit of power developed.

12. Ability to move itself and train of one-half rating in the event one set of its machinery or engines becomes disabled.

On a railroad the principal work to be accomplished is the movement of trains from one terminal to another on time, and locomotives are now expected to perform equally well work of the most varied and exacting nature. Speed limits and train loads are increasing each day, and will, no doubt, continue to do so, as the maximum expansion of car equipment and the length of trains, under favorable conditions, have not yet been reached.

The first requirement by the transportation of the mechanical department is locomotives of such capacity and in such condition as will move the greatest gross tonnage that can be concentrated per foot of track space in one train at the fastest rate of speed that the track and dispatching facilities will permit, with a proper degree of safety.

How well this demand can be met in one steam locomotive of the present gage and clearance limits by flexibility and simplicity in design, maximum proportion of adhesive to total weight, good material and construction, pure heated feed water, quickened circulation, compounding, superheating, substantial maintenance, intelligent operation, and other essentials, is a question that must be determined in the very near future; and from this determination will proceed the conclusion as to the proportions of each type of locomotive required in the motive power stock for a large modern railroad system.

Railroads are not operated to save fuel, nor to have locomotives that it does not cost much to maintain and

* A paper read before the New York Railroad Club by Mr. J. E. Muhlfeld, general superintendent of motive power, Baltimore and Ohio Railroad.

operate, and while economy must be considered as secondary to getting trains over the line, at the same time, the tractive power required, and the limits given within which to acquire this, make it necessary that locomotives be now so designed and constructed that more work will be produced per unit of fuel consumed, and the result should be economy. Whether this economy can be derived from the use of turbine, internal combustion, pneumatic or electric locomotives, or by a further practical development of the present type of steam locomotive, will depend entirely on the local conditions and requirements, and remains for the present and future progress to determine.

It is a fact that electricity as a motive power is superseding steam in many cases for the handling of suburban passenger and freight traffic, and that it may displace the latter for through passenger service, but it will be some time before electrical energy will supplant steam power for the handling of heavy tonnage for any considerable distance.

While the construction and operation of electrical locomotives is still in an experimental stage, their performance during the past year, under varying weather, rail and service conditions, when compared with steam locomotives, shows a cost which will make their present use prohibitive, when fuel must be used to generate power, except in cases of absolute necessity.

Given an electric locomotive complete and crewed, ready for operation, it would require:

For terminal handling: A running repair shed with drop pit and auxiliary facilities; tracks and switches; inspection pit and sand, repair material and general stores supply. For maintenance: A general repair shop and equipment, and many expensive extra parts for quick repairs and renewals for locomotive and plant. And for line operation: Standard gage tracks; sand supply station; power plant building; boilers; draft arrangement; stokers; coal, water and ash intake storage and distributing appliances; coal crushers; superheaters; economizers; feed water heaters and pumps; condenser equipment; heating, fire protection, compressed air and general and detail lighting systems; engines and generators; exciters; switchboards; piping; oiling system; overhead cranes and machine tools; general and auxiliary feeder and distributing systems; transformers; rotary converters; storage battery; overhead or surface contact lines; bonding; insulation; safety cut-out device; lighting protection device, etc.

Given a steam locomotive complete and crewed, ready for operation, it would require:

For terminal handling: A running repair shed with drop pit and auxiliary facilities; tracks and switches; turntable; ash pit; and coal, water, sand, repair material and general stores supply. For maintenance: A general repair shop and equipment, with a few inexpensive parts for locomotive repairs. And for line operation: Standard gage tracks, and coal, water and sand supply stations.

Therefore, in building a large locomotive for to-day such design and construction must be adhered to as will not only fulfill the present speed and heavy tonnage requirements, but which will remain modern for several years to come, and in the constructive features must be a combination that will insure the most conversion into energy per unit of fuel consumed, and result in the greatest efficiency and economy with respect to cost for installation, maintenance and operation.

The general features for a modern locomotive may be summed as a reasonable first cost; maximum efficiency for the service, within the track, weight and clearance requirements; the greatest proportion of adhesive to total weight; a capacity to handle the heaviest gross tonnage practicable at the highest desired speed; the greatest permissible distance between coal, water or power stations; economy as regards maintenance and fuel and water consumption; a substantial construction of the least number of parts; and a capacity to perform continuous service without liability of failure.

The general requirements for electric locomotives have already been reviewed.

For steam locomotives the merits of a three-cylinder balanced compound type, with one high pressure inclined cylinder between the frames and a low pressure cylinder at each side outside the frames, having the high and low pressure cylinders connected by ordinary pistons, crossheads and main rods with the main driving axles and wheels, with cranks at 120 deg., and using a combined receiver and intermediate superheater for the passage of the exhaust steam between the high and low pressure cylinders, should be investigated for passenger and fast freight service.

For slow freight service, where a greater tractive power is desired than can be obtained from a properly designed consolidation type locomotive, it would appear that the use of the Mallet articulated design, as already described, would result in the movement of the greatest tonnage per hour over a single piece of level or mountainous track, with a proper degree of safety, efficiency and economy.

At this period, when changes in alignment and gradient, and reconstruction of old as well as the construction of new steam railroad lines, are being considered, there is every opportunity for motive power engineers to demonstrate the advantages of electric over steam traction.

Some of the mountainous steam railroads present many attractions in the way of permanent and concentrated supplies of cheap coal, gas, oil or water for power, and water for condensing and cooling purposes, which, in combination with suitable means for generating, conveying and utilizing electric current for locomotive traction power, might enable a profitable continuance of lines which are now being abandoned, or which, under the present operating conditions, must sooner or later be replaced at a very great cost.

However, before electricity can supersede steam for tonnage service it must be demonstrated practically from actual installation and operation, and not theoretically, that the results which electrical engineers are predicting will be forthcoming, as railroads are not generally making heavy expenditures to increase the business and revenue and reduce operating expenses unless they have reasonable assurance of the net results.

It has been said that for the handling of heavy tonnage electric locomotives have extreme advantages; especially on heavy grades, in regard to speed; this on account of the steam locomotive not having the same endurance due to a limited supply of steam.

Up to the present time, from actual performance, it has not been found that electric locomotives having almost equivalent tractive power, when handling heavy tonnage on severe grades and curvature, can operate at greater speed than steam locomotives.

Of six geared and gearless electric locomotives now in service or under construction, all are different in design, system or method of controlling, and there is every indication that none have yet practically demonstrated that they can meet the requirements for efficient and economical operation and maintenance.

Should it be necessary, from an electrical standpoint, to continue the use of gearing between the motors and driving wheels, as well as the large number of small diameter driving wheels, for heavy tonnage electric locomotives, to obtain the requisite tractive power, it would be interesting to know how the predicted largely increased speed, as compared with steam locomotives, is to be obtained with a reasonable efficiency and maintenance cost.

The arrangement of the propelling gear on the electric locomotives recently purchased by the Valtellina line in Italy, is one that appeals to motive power people who have experienced difficulty with other types of electric locomotives now in service.

The working capacity of an electric locomotive having a total weight of 160 tons, with 42-inch diameter driving wheels, at a speed of 10 miles per hour on 1 per cent grade, is about 1,500 tons in the train, excluding the locomotive. The working capacity of a steam locomotive having a weight of 167 tons for the engine and an average weight of 58 tons for the tender, with 57-inch diameter driving wheels, at a speed of 10 miles per hour, on 1 per cent grade is about 2,200 tons in the train, excluding the weight of the engine and tender.

In no instance when operating a steam locomotive of the above capacity under the most severe conditions, has it been found that the boiler could not furnish all the steam required to develop the maximum tractive power of the engine.

Comparing the horse-power developed, it has been found that the first cost, cost for operation and maintenance, number of and weight on driving wheels, and number of large bearings requiring lubrication, has, for the electric locomotive, been in excess of that of the steam locomotive, and there has been no benefit with respect to increased average speed on 1 per cent grade.

A steam locomotive in one section can be designed and placed under the control of one engineer and one fireman, which will economically develop as much tractive power as may be necessary to haul the greatest amount of tonnage that can be concentrated in one train of suitable size for safe and quick handling over a division.

The advantage of the electric locomotive for the handling of heavy tonnage would be in the increasing of the capacity of the line, and it might be that the increased business handled would justify an increased cost for installation and operation of electric locomotives as compared with steam locomotives.

When compared with ordinary modern steam locomotives the advantages that the electric locomotives have are on account of no tender for coal and water, which reduces the average dead weight about 60 tons per train, which is equivalent to one car and about 40 tons paying load per train, provided the same drawbar pull can be obtained per equivalent horse-power and factor of adhesion, when compared with steam locomotives. Electric locomotives will give the advantage of a high average speed obtained for the same weight on driving wheels, while the more rapid acceleration and a lower maximum speed results in less total power required to drive the train and a lower braking pressure for stopping.

The life of the steam locomotive could be maintained indefinitely by the same process as will be required to keep electric locomotives in serviceable condition, but it has been found during the past that it is more profitable to dismantle obsolete equipment and replace it by entirely new equipment than to continue the old stock in service. This will no doubt apply to electric locomotives when they may have reached the same average age that now results in the dismantling of steam locomotives.

From present indications, any benefit from the increased life of the electric locomotive, as compared with the steam locomotive, would be overbalanced by the cost due to continual renewals and repairs on account of ordinary wear and tear.

The cost for the first installation of power plants for generating current is too high. Under the average conditions the actual cost for the complete installation will range from $100 to $150 per horse-power developed, which is from seven to ten times as much as the cost per horse-power developed in the ordinary types of modern steam locomotives at a speed of 10 miles per hour.

The present types of stationary boilers are too costly, and require too much floor space per horse-power developed. The merits of good superheaters, economizers, feed water heaters and draft appliances, should be carefully investigated for the purpose of increasing the efficiency and economy of steam boilers, which should be designed to produce more horse-power per cubic foot of space occupied.

The cost for coal, ash and water supply, storage and distributing appliances, as well as the expense for generators, high tension lines, transformers, exciters, converter and feeder switchboards and appliances for the distributing systems, all contribute largely to the high initial cost for power plant installations.

The size of the current generating device should not be enlarged to such an extent as will necessitate expensive foundation and building construction, overhead cranes and runways and concentrate too much power in one unit. A combination of reciprocating, turbine and internal combustion generator sets should be given consideration for the purpose of efficiency, reliability and economy.

There is no doubt but that steam locomotive boilers and engines are decidedly more extravagant in fuel and water consumption than the modern power plants which are equipped with all of the refinements. At the same time there is a certain advantage and economy in the operation of a locomotive which in itself produces the power that moves it as compared with one that is dependent upon an outside source for its propulsion, and which results in transmission and conversion losses of the current before it is applied at the motors.

To electrical engineers the report and the remarks will appear to be most unfavorable for the electric locomotive operation. This, however, should not interfere with the development of an electric locomotive and power system which will give more efficient and economical results than what may have been up to the present time, or can be, obtained from steam locomotives.

What the stockholders and heads of railroads generally desire is to originate and move the greatest amount of business possible with the least cost to capital and operating accounts.

The motive power engineers must co-operate in working up designs of electric locomotives. Should difficulty be experienced on account of armature burning out, the electrical engineer should not insist on the weight on driving wheels being reduced to remedy the trouble; and at the same time the mechanical engineer should not require the use of pilot wheels and add unnecessary and ineffective parts and weight, if locomotives can be made to operate safely and efficiently without them.

The locomotive problem must be attacked from a transportation and motive power, and not from an electrical and mechanical engineer's viewpoint. There are sufficient locomotives of all kinds now under construction and in service on American railroads to give correct data as to what can be accomplished under varying conditions by either the electric or steam method of developing tractive power, and if unwhitewashed reports of their performance can be obtained it will be of invaluable assistance to electrical and mechanical engineers generally in meeting the present and future motive power requirements.

THE POSSIBILITIES OF THE HIGH-SPEED RAILROAD.

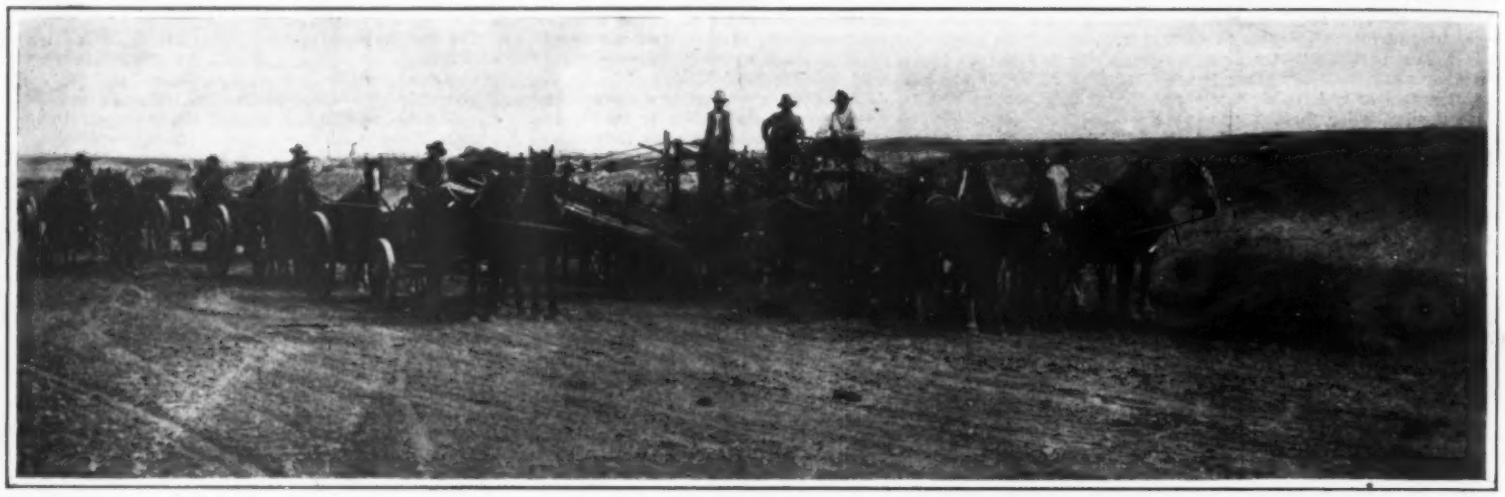
THE application of the electric motor to meet the immediate needs of railway terminals at large cities has drawn attention for a while from the so-called high-speed railroad, the expression meaning here a road on which a speed of 100 miles an hour or more may be made on regular schedule. It has been shown pretty conclusively that there is now no physical reason why such speeds may not be attained and held, so that the problem has resolved itself into one of securing sufficient safety; that is to say, of building a suitable roadbed and of devising a suitable system of controlling the trains. The electric motor furnishes the means by which any speed which the roadbed or the car itself will stand can be maintained indefinitely.

Aside from the design of the roadbed, the method of controlling the trains therefore becomes the next in importance. As has been said, it is obvious that some extension of the block system must be employed in which the blocks are longer and the safety devices much more complete than anything in use to-day. One plan would be to divide the road into long blocks, each block ending at a stopping point, and to allow no train to start from one station until the preceding train had left the one ahead. Another plan recently proposed contemplates dividing the road into shorter blocks with intermediate blocks each long enough to enable a train to be brought to a stop on it. The power supplied to these blocks is to be controlled by the train on the next block ahead, and is to be cut off automatically from these intermediate blocks until there is no train in the block ahead.

The interesting feature about these plans is the fact that the very means which makes it possible for us to attain such high speeds is the means which will enable us to make use of them. The electric motor is the only driving mechanism considered for such high speeds, and the electric railway system is one which readily adapts itself to automatic control. On such a road, not only would the signals be operated more or

less automatically by the trains themselves, but the safety devices which would be necessary for the road would also be controlled electrically. There would be no difficulty in having the power supplied to one whole block cut off automatically by the presence of a train on another part of the road, a feature difficult to obtain if any other motive power be used.

The high-speed road is more than a probable development in railroading, and that it will be purely electrical there seems at present to be no doubt. It is because the power is supplied to the moving train from a stationary power-house that such speeds may be maintained, and the movement of the trains may be controlled automatically.—Electrical Review (N. Y.).



EXCAVATING ON THE MAIN DITCH WITH DITCHING MACHINES. THIS PICTURE SHOWS HOW THE MACHINE DELIVERS EARTH INTO THE ACCOMPANYING WAGONS AS IT MOVES ALONG.

IRRIGATION IN WESTERN CANADA.*

By LAWRENCE J. BURPEE.

EVER since the followers of Brigham Young turned the deserts of Utah into a terrestrial paradise, the reclamation by irrigation of the great semi-arid belt which runs north and south through the continent has steadily progressed. For a time the importance and value of irrigation were only imperfectly realized. There were still in the western half of the United States millions, and hundreds of millions, of acres of well-watered lands suitable for cultivation. But as the tide of settlement pushed steadily westward, and the best lands were taken up, the reclamation of the vast acreage of semi-arid land—land which held all the properties requisite to profitable farming, but lacked a sufficiency of moisture—became an object of increasing moment. The work of bringing these lands under irrigation, which at first had been left to individual enterprise and haphazard methods, was presently taken up by large corporations, and placed in the hands of experienced engineers. Finally, the federal government took hold of the mattter, and it has now reached the stage of a great national undertaking.

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

able and waiting for settlement three hundred million acres of the finest land on the continent.

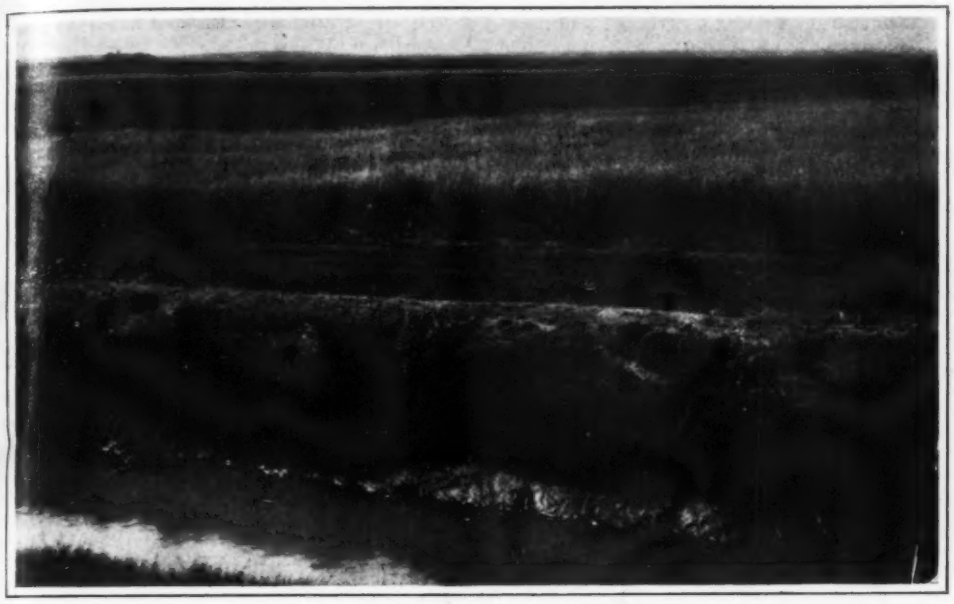
The explanation of this apparently anomalous condition is not far to seek. The southern half of the Province of Alberta, which is practically conterminous with the semi-arid belt in the United States, is climatically more favorably situated than any other portion of western Canada between the Great Lakes and the Rockies, and for this reason southern Alberta has been from the very first a favorite field for immigration. The meteorological good angel of southern Alberta is the Chinook wind, whose marvelous feats would hardly be credited by one not familiar with western climatic conditions. When a real Chinook blows, says one who has made a close study of the subject, "the thermometer often rises in a few hours from 20 below to 40 above zero; the snow, which in the morning may have been a foot deep, disappears before night; everything is dripping; but before another night falls all the water is lapped up by the thirsty wind, and the prairie is so dry that a horse's hoofs hardly make an imprint as you take your first welcome canter over the trail." As the north wind which brings 20 below is rare, and the Chinook is a frequent visitor, the average temperature of southern Alberta is exceptionally mild, the winter approximating more closely to that of the Pacific coast than any other part of Canada. I have before me a series of photographs taken in southern Alberta in the winter of 1900 (an average winter). One shows a game of baseball on Christmas day; another, children playing bare-headed on the 14th of December; a third, bicycling in January; and the last, boys playing marbles on the 6th of March. Is it to be wondered that settlers who found their way to southern Alberta were loth to leave it for the extreme cold of a Manitoba winter, and when they found that the meager rainfall made wheat growing a failure, instead of abandoning the country turned their energies toward the production of a substitute for rain?

Apart also from this general reason for the reclamation of southern Alberta, there is a special reason which applies to the Calgary district. When the main line of the Canadian Pacific Railway was built, the company received from the Dominion an enormous land grant, comprising the odd-numbered sections in each township in a belt twenty-four miles wide on each side of the railway, the even-numbered sections being retained by the government for free homesteads. The railway company was given the privilege of choosing its own lands, and for a long time declined to have anything to do with the discredited semi-arid belt of Alberta, through which its main line ran for several hundred miles. Finally, however, when negotiating with the government for the transfer of the last installment of its land grant, the company decided to attempt an irrigation scheme on a large scale—a scale in fact far beyond anything that had yet been ventured on this continent—and to this end agreed with the government to take the balance of its land subsidy in semi-arid Alberta, on condition that the government would surrender the even-numbered as well as the odd-numbered sections, thus giving the railway a solid block of land, three million acres in extent. This the government agreed to do. The resulting irrigation project will be described presently. For the present it is sufficient to note that both natural and artificial conditions combined to push forward the reclamation of the Canadian semi-arid belt, long before the available supply of well-watered lands to the east and northeast was anything like exhausted.

A STEAM SHOVEL AT WORK.

IRRIGATION IN WESTERN CANADA.

The irrigation movement, which had its inception in the southwestern States, and, broadly speaking, has worked steadily north, has within the last few years crossed the international boundary. As the Mormons were first to realize and demonstrate the vast potentialities of irrigation in the United States, so at a later date they were pioneers in the reclamation of the semi-arid belt of western Canada. In their settlement at Cardston, south of Lethbridge, and a few miles north of the international boundary, they have achieved the same marvelous results in the transformation of barren lands into lands of exceptional productiveness, that they had formerly done in Utah. Their Gentile neighbors were not slow to profit by the Mormon example, though for some time the irrigation was done almost entirely by ranchers for stock purposes rather than farming.



A FIELD OF OATS ON IRRIGATED GROUND.

Alberta had, in fact, been taken hold of by the ranchers at an early date as the most suitable district in western Canada for cattle and horses. Its mild climate, slight snowfall, and abundance of naturally-cured bunch grass made it an ideal country for ranching; and when in the early days it became discredited as a field for profitable farming, the cattle men at once came in with their herds and monopolized a large section of the territory. The slight precipitation—ten or eleven inches as against thirty in the rain-belt districts farther east—which proved so disastrous to farming, was rather an advantage than otherwise to the ranchers, as a slight rainfall meant also a slight snowfall, and cattle could graze on the prairie throughout the winter without shelter of any kind except such as nature afforded.

Once in the hands of the ranchers, the fate of the country seemed sealed for all time. Ranchers are as bitterly opposed to thick settlements in their country as were the old-time fur traders. Their industry demands ample room—wide, unfenced ranges for their cattle, sheep, or horses. They much preferred that farming operations should be confined to the eastern half of the Territories.

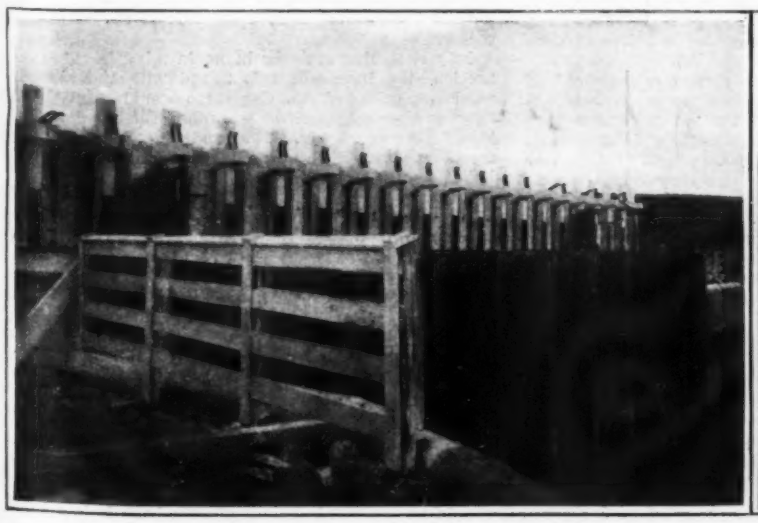
But the farming element in southern Alberta, though numerically weak, was plucky and enterprising, and refused absolutely to be driven out by either the ranchers or the climate. The Mormon and other experiments on a relatively small scale had demonstrated the fact that, with sufficient moisture, the soil of Alberta was splendidly adapted to both wheat and mixed farming, and the farmers now got together and determined that that soil should not lie idle if they could help it. Irrigation was the solution of the problem, and irrigation they determined to have.

In 1893 the various tentative efforts toward irrigation culminated in a larger and more comprehensive scheme. The Mormon and other small projects had been in the extreme southern parts of the province, but this larger scheme materialized somewhat farther north. A channel was cut from the Elbow River to serve the district west and southwest of Calgary. As a result land hitherto unproductive yielded splendid harvests—equal to the best of the famous Manitoba districts. The southern or Lethbridge district now followed suit. The Canadian Northwest Irrigation Company (now merged in the Alberta Railway and Irrigation Company) was incorporated and took up the work with commendable energy, beginning the construction of a system of irrigation canals on a much more ambitious scale than had hitherto been dreamed of in Canada. In this work it had the active support of the entire community, who were now firmly persuaded of the advantages to be derived from irrigation. The Galt canal, as it is called, with its 190 branches and ditches, over five hundred miles in length, now serves 650,000 acres of land in southern Alberta. The work so far has cost half a million dollars. It is estimated that the increased value given to this land as the result of irrigation amounts to $2,500,000. It can readily be seen how enormously the value of the entire semi-arid belt of Canada would be enhanced by a scheme of irrigation covering the entire territory.

What such a general scheme would involve may here be briefly summarized. In a special report issued by the Dominion government, it is stated that the semi-arid belt of western Canada covers 99,108 square miles, or 63,429,120 acres of land. The government experts report that by utilizing the existing supplies of water by means of irrigating canals, at least 15 per cent of this area, or say 9,515,000 acres, could be made available for farming purposes. The remaining 85 per cent would still be available for grazing. There is consequently ample room for both the farmer and the rancher in Alberta.

The general slope of this southwestern portion of the Canadian Northwest is peculiarly favorable to a scheme of irrigation. Roughly speaking, the continental divide which separates the waters flowing into the Gulf of Mexico from those which find their way to Hudson's Bay follows the international boundary across the prairie. Further, the watershed from the eastern side of the Rockies is so distributed that it can readily be directed wherever most needed. The country slopes gradually from the foothills on one side and the international boundary on the other toward the east and north. The irrigation problem is therefore already half solved. Tap the natural water supplies that come down from the foothills, and that waver along the summit of the continental watershed, and the law of gravitation will do the rest. Nor, comparatively

MAIN CANAL TWO MILES FROM THE HEADGATES.



HEADGATES OF THE MAIN CANAL.

A DEEP CUT IN THE MAIN CANAL.

IRRIGATION IN WESTERN CANADA.

speaking, is it necessary to do a great deal of digging. In many places artificial waterways will only be necessary to connect one *coulée* with another. There are also an abundance of natural depressions which can readily be converted into reservoirs for the conservation of surplus water, as has already been done in the case of the Galt canal.

Meanwhile, pending the application of irrigation to the entire semi-arid belt of southern Alberta—a project which could only be undertaken by the Dominion government—the Canadian Pacific Railway has undertaken an irrigation scheme of very large proportions. The land transferred to the company by the Dominion government, as already explained, lies between Medicine Hat and Calgary, bounded on the south by the Bow River, and on the north by the Red Deer. The railway runs through its entire length. Mr. Elwood Mead, and other irrigation experts who have examined this land, state without hesitation that it is admirably adapted to cultivation so far as the quality of the soil is concerned, and they are convinced that irrigation is not only practicable, but that it will result in adding to the Canadian grain belt a large section of land hitherto unavailable except for grazing purposes.

Having secured this land from the government, the Canadian Pacific Company proceeded to mature its scheme. Engineers were sent out to examine and report upon the district; estimates were prepared, and plans and specifications for the gigantic work contemplated, and finally tenders were called for the first section. In the spring of 1904 a contract was let to a firm of contractors in Vancouver for the work, the price being three million dollars, and the canal, or rather its first section, to be completed inside two years. This first section is really the main canal, which starts from the east side of the Bow River, about three miles below Calgary, and runs for twenty miles across the level prairie. The canal is 60 feet wide at the bottom, 10 feet deep, and is designed to carry two thousand cubic yards of water per second.

This trunk canal brings the main body of water from the Bow River to the most convenient point for distribution. At its easterly end the water is turned into three secondary canals, located along the heights of land. By this means the irrigating streams are conveyed with the minimum of effort to the lands intended to be brought under cultivation. The company expect eventually to have four hundred miles of these canals along the Bow River, and the major portion have already been located. Of the three million acres in the tract acquired, about one-half will be placed under water, the balance being reserved for grazing and dairy farming.

The completed system of irrigation canals will cost in the neighborhood of $4,000,000. In building the trunk canal alone, which is now nearing completion, 250,000,000 cubic feet of earth will have been taken out. The work is being done by means of steam shovels operated on railways, with every other modern engineering appliance which would facilitate the early completion of the canal. Considerably over half a million acres are now under water, and the irrigated districts are rapidly being extended on every side.

A comparison of the cost of this Canadian irrigation project with similar undertakings in the United States and India, to go no farther, brings out some rather interesting results. The Canadian Pacific Company estimate that their irrigation canals in Alberta will cost, taking in everything, about $2.75 per acre. According to the report of the United States Industrial Commission, the cost of irrigation in the Western States has been from $2 to $5 an acre in the original pioneer ditches, increasing to $12 an acre in the larger and more elaborate undertakings. The average annual cost of conveying the water has been about $1.25 per acre, including cost of repairs and maintenance. In India, where 19,000,000 acres of land have been reclaimed at a total cost of $127,000,000, the cost has been found to be $6.65 an acre, the government of course having the advantage of very cheap native labor. The explanation of the very much reduced cost of the Canadian project is mainly the unusually favorable lay of the land, which, with the exception of a few deep cuttings and an occasional flume to carry the canal over some intervening *coulée*, will make the work of excavation comparatively light.

Irrigation in Alberta has not only increased the area of land adapted to the profitable cultivation of wheat, oats, and barley, but corn, potatoes, and other root crops are also being raised in rapidly-increasing quantities, a ready market being found for the entire surplus over local consumption in the mining districts of British Columbia, direct railway communication between Lethbridge and the mining country being afforded by the Crow's Nest branch of the Canadian Pacific Railway. One of the most interesting results of irrigation in the Lethbridge district has been the establishment of a large beet-sugar factory, supplied with beets grown on irrigated lands, which have been found to be peculiarly well adapted to this particular crop.

The practical wisdom of this widespread scheme of irrigation in western Canada is further illustrated by the fact that up to the present time, in spite of the dismal warnings which greeted their acquisition from the government of these semi-arid lands, the Canadian Pacific Railway Company have disposed of one hundred and fifty thousand acres of land in the Calgary district, at prices aggregating three-quarters of a million dollars.

The success of the Canadian Pacific Railroad's project has also encouraged others to invest capital in irrigation. The Robbins Irrigation Company, representing a group of English capitalists, has entered into an agreement with the government of the province of Saskatchewan to spend a minimum of $1,000,000 on the irrigation and improvement of 300,000 acres of land lying between the Bow and Belly Rivers, to the eastward of the Canadian Pacific Railroad irrigation works. It is the intention to settle on the irrigated tract a number of Canadian and American farmers who are familiar with the working of irrigated lands. Sugar-beet and canning factories will be erected by the company in the town of Medicine Hat, the climate of this district being particularly favorable to the production of many kinds of vegetables and small fruits.

INDUSTRIAL APPLICATIONS OF GYPSUM.—I.*

By ROBERT GRIMSHAW.

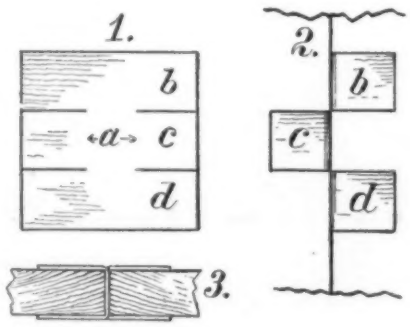
IN entering upon a discussion of this subject, we must bear in mind that just as there are two general classes of steel, temperable or hardenable and non-hardenable, so there are two equally distinct varieties of gypsum or plaster of Paris—the quick-setting and the slow-setting; or stucco plaster and building or hydraulic plaster. These differ from one another in their manner of preparation and use, and in their physical qualities, although chemically they are not so far apart.

Stucco plaster is burned at a low temperature, and still contains considerable of the original water of crystallization. Its principal use is where good casts rather than hardness and closeness of pores are desired. It owes its value in this connection to the fact that when the "mix" is just about to take its final set, it expands sharply and tends to enter every crevice and cranny in the mold, and stay there.

There are three principal methods of getting therewith casts of a clay or other model.

The first method yields but one cast; the other two permit of obtaining from six to six hundred, according to the nature of the article and the care taken in molding and casting.

According to the first method, the original is coated with a thin wash of dark-colored plaster cream, well applied with a brush so as to leave uncoated no crevice in the original. Next comes a well-laid-on layer of stiff plaster from two to six inches in thickness, according



METHOD OF SECURING THE JOINTS.

to the subject. When this has hardened, the clay original is removed by digging out and washing, so that no clay remains in the mold, even in the finest interstices, representing the finest projecting parts of the original. The next step is to fill these fine crevices with a very thin plaster cream, so as to insure a sharp cast. This satisfactorily attained, the main cavity of the mold may be filled with a stiffer mass and allowed to set. To insure the penetration of the first pouring into the finest interstices, the mold is "rinsed out" as it were; the swaying motion throwing the liquid into the crevices and letting the air escape. If it is desired to make a light casting, either to save plaster or for any other reason, the heavier portions need not be filled; to reduce weight, the core may be dug out, and to save plaster, a core of wood or other material may be introduced at the desired distance from the periphery of the mold, to determine the thickness of the casting. The mold is then to be removed by hammer, knife, and chisel; the dark layer tells how deep to go.

The advantage of getting a plaster cast instead of a clay model is that the cast is sightlier and will not crack with dry weather nor slump down in wet.

To make a two-part plaster mold of a flat object, as the human hand in outstretched position, or a coin or medal, a layer of soft plaster is prepared, and the object to be cast pressed therein until the natural parting line is reached. It is advisable to oil the surface of the original, to prevent it sticking in the mold. The surface of the lower mold may be given a light coat of shellac, and then a fence having been built out of cardboard, to limit the size of the upper mold, plaster is poured upon the original and lower mold. When this has set, the upper part may be lifted off, and the original withdrawn from the lower half of the mold. In order to avoid losing the mold by breakage at the time of making, or later, it is well not to be sparing of plaster.

If it be desired to make a cast of the human foot, the part must first be thoroughly oiled, then the parting lines drawn thereon; or perhaps it would be better to make these beforehand. Then fine, strong cords are laid along the parting lines, and held there with a little fine plaster cream. The spaces between the toes must be filled with well-oiled cotton. Plaster is then to be laid on in considerable mass, care being taken not to lose the ends of the parting cords. When the mass has nearly set hard, both ends of each cord are to be drawn, so as to make sharp "parts" in the mold. When the mass has set hard the different parts are to be drawn away from the foot. In choosing the parting places, particular attention must be paid to getting clean work at the ankles, and if the cotton between the toes is not rightly arranged there will be difficulty in getting the foot free of the mold. The foot should not be left too long in the mold, as it is apt to swell and increase the difficulty of withdrawal. The work should be sharp enough to show the "goose-flesh" on the skin caused by the cold plaster.

Where many casts are to be made from a part mold it is best to shave its outer surface smooth and to give it a coat of shellac, and then to make a jacket of plaster over the whole, to keep the parts together in pouring.

In pouring most molds it is desirable to leave vents for the air to pass out; the resulting projections on the cast can be removed with a knife.

The third method of molding permits the use of originals that are slightly undercut. Here the mold is made of a glue composition something similar to that used for printers' rollers; the main components being glue and molasses or glycerin. The original may be of almost any kind—wood, metal, plaster or what not. It is first coated with a liberal clay jacket which is wiped down smooth. Then there is made over this an outer jacket of plaster. The thickness of the clay covering determines that of the glue mold. The original and the clay covering being removed from the outer plaster jacket, the clay is then washed off the original, the latter inserted in its former relative position in the outer jacket, and the space between the two poured with the glue composition. The original may then be removed from the glue mold, and this poured with plaster. In removing the original or cast, the mold gives considerably without danger of breaking or slumping.

In order to insure getting castings that will bear a little rough handling, the glue form may first be rinsed out with a thin plaster cream and then stuffed with a mass in which excelsior or other mechanical binding material is freely used.

In order to make a setting for a broken leg there is first wrapped around or laid upon the part to be cased, sterilized cotton wool or flannel; then over this there are wrapped gauze strips which have been thoroughly "stuffed" with the finest, most rapidly-setting plaster; the bandages are then wet with warm water, or if the work is done quickly enough each strip may be drawn through the warm water before it is wrapped around the limb.

In using plaster as a cement it must be remembered that it will not hold smooth surfaces.

In the ceramic industries plaster of Paris is the right bower, or sheet anchor, or whatever one chooses to call it, that will indicate its value and indispensability. It owes its high position to two qualities—the fact that it can be so readily formed into almost any desired design, and its great porosity and absorbent nature. This being the case, molds may be readily made in any desired quantity from the original design, or the gypsum itself may be employed in making the original. These molds may be made of any desired degree of porosity, to suit the character of the mass that is to be poured or pressed therein. Further, the molds are light—which is more than can be said of the slate molds which are so largely employed by pewter founders.

A most important use of gypsum is in interior decorations, and these may be either cast and applied, or swept in place. Here one can use either pure plaster of Paris, or a mixture of that and lime alone, or sand and lime together, or layers of mixture overcoated with pure gypsum.

In using lime as an adulterant, the plaster may be run down as low as 20 per cent by weight. As regards the amount of sand that can be worked in, that depends on the sharpness—of the sand, not of the contractor. The strength of the mass may be increased by the addition of glue to the water, also by the employment of calves' hair; cows' hair is apt to be too coarse.

Only one thing must be borne in mind in this connection—the lime which is mixed with the gypsum must not be too fresh, else there would result blow holes in the surface of the work, and further the mass would set too quickly. The sand must be sharp and free from clay. Either hard or soft water may be used, but it should be clean.

In later years builders have made use of many kinds of mixtures of stucco plaster with less costly materials, in the form of slabs for partitions and even outside walls, and have also made use of plaster in connection with wire cloth of more or less open mesh, for partitions made in place, as distinguished from those made up of previously-manufactured slabs or boards. Most of these forms have served their purpose well, when the adulterant was not too plentiful or too worthless. Sand, lime, ashes, cocoa fiber, excelsior, hair, rushes, hoop iron, and various other binding and reducing materials have been used with more or less success. Unfortunately, the use of coal ashes and of old plaster has given such material a bad name. But where good materials are properly used, there has been no dissatisfaction. And as there is no patent on the simple forms, which are mostly the best, it is a pity that the use of plaster in building has not been more widely introduced. In Europe, gypsum flooring tiles, where materials are to be stored, and there is not

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

much tramping thereon, are not unknown; but the principal application is for what Americans would call plaster lumber for partition walls. The usual thickness is from one to three inches; the width is generally a fraction of a meter—25 and 50 centimeters being the most usual; and the length runs from two to two and a half meters. When we remember that such "boards" are lighter than water, can be sawed, cut, and planed, hold screws, hooks, and nails quite well, and can be made at any season of the year, it is a wonder that they are not more used. They are dry, fireproof, and bad conductors of heat and sound; further, they do not harbor vermin. Their only fault—I am speaking of those which are made of stucco plaster—is that they have not a very high compressive strength, so that although they will bear their own weight as well as a brick wall, they cannot be relied upon to hold up roofs and upper floors. Where, however, it is required that a partition wall shall carry weight, the use of a suitable mixture of stucco and hydraulic gypsum will solve the problem in a satisfactory manner. If required for outer walls stucco slabs should be protected against weathering; asphalt would be good enough but its appearance is not highly attractive, and a wash of cement is therefore preferable. In this connection, however, it must be remembered that cement should not be applied directly to the plaster; there should be a preparatory coat of lime wash, or better yet a very thin lime-plaster coating.

Gypsum plaster has the advantage in dyeing establishments, tanneries, wash-houses, etc., of preserving iron beams, etc., from rusting, and wood from rotting.

Where plaster lumber is used, the joints may be secured either by wire nails driven in diagonally where there is no studding, or by sheet-iron binders made out of square pieces each with two cuts from two opposite edges, as in Fig. 1, in which *a* represents the thickness of the planks, and which pieces are folded over as seen in Fig. 2, which represents part of a joint, and shows how the wings of the clamping piece are folded over. Of course, except in the case of warehouses and other buildings where the appearance does not matter, partition walls thus clamped need a coat of plaster to make them sightly. It is usual to make such plaster planks smooth on one side and rough on the other; where they are to be given a finishing coat, the rough side is put out. I have cast them on glass and marble slabs to get the smooth side; the rough side is easily enough obtained, but it is well not to err on the side of smoothness on the face which is to hold a plaster coat.

Where the slabs are very long it is wise, for safety in transportation, to stiffen the slabs with rushes, twigs, or even straw, laid lengthwise, as this is the direction in which the greatest stiffness is required. Thick twigs are, however, to be avoided, as they cause cracking by absorbing water from the plaster; it is better to use thin ones and to soak them well in water before using.

It is a good plan to make walls of a double layer of thin slabs, one layer running vertically and the other horizontally; wire nails from one layer to the other will give great stiffness. Where it is desired to secure great non-conductivity to heat or sound, there should be an air space between the two layers of the double wall; and in this case vertical studding may be used, or for greater cheapness one strong upright at each end of the wall, with tightly-strained galvanized wire (about No. 4) to give stiffness against lateral strains. But another way, and a very good one, is to cast the slabs with ribbed projections on the back, in such direction that they will cross each other in the wall and give mutual support, while still preserving in great part the air-space feature.

If one wishes a roof that shall be fireproof, non-conductive to heat, and light on the rafters, stucco plaster will solve the problem—if rightly used. Thin plaster boards are nailed on the rafters, then the whole run with a three-quarter-inch layer of gypsum beton, consisting of stucco plaster with either sharp sand or good sharp screened coal ashes. Over this comes a layer of asphalt roofing paper, and the whole is then given a coat of iron ore ground in fish oil, and strewed with sand or fine gravel while the paint is still wet. This is of course best suited for comparatively flat roofs. For a so-called Gothic roof, say 60 degrees, the rafters may be overlaid with inch hemlock boards; then asphalt paper, then plaster and ashes (laid on with a float) about half an inch or less in thickness; then slates. A slate roof thus laid will not rattle in the greatest storm that ever comes up, and all the lightning-rod men and telephone men in town can climb over it without being able to loosen a slate.

Up to this point I have considered principally stucco slabs or boards made elsewhere than at the place of building; there remains to be considered a method of construction very largely adopted in Germany, in which galvanized woven wire, expanded metal and the like come into play, and the surfaces are formed of fresh plaster in the desired outlines and surfaces. The mass is usually a mixture of lime and gypsum often with cow hair as binding material and sometimes with sharp sand. For partition walls the wire cloth is strained between standards, plastered on both sides and then given an outer coat with no hair. To prolong the time of setting, and also to increase the strength of the mass, glue water is often used.

A more expensive partition is made by using two layers of wire cloth with a space between, and plastering each on one side only. Many of the apparently massive vaulted ceilings that one sees in modern buildings in the old style are only wire cloth and plaster; the short thick columns are of studs overlaid with wire cloth or expanded metal and given a gypsum jacket, which is usually carried out in scagliola or breccia imitation. Sometimes, indeed, such columns conceal the steam and gas pipes, and in some cases they are even the chimneys.

Another constructive feature which we owe to the French is ceilings of I beams with wooden cross laths between them, on which plaster is poured, after a temporary board ceiling is laid under the beams to keep the plaster from going clear through. When the temporary ceiling is removed, the under side of the layer of lath and plaster is given a finish coat, and the floor is laid on the beams as in the case of any other ceiling.

I reserve the consideration of the applications of hydraulic gypsum for a separate article.

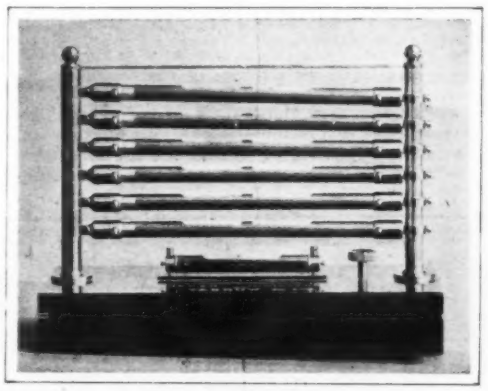
(To be concluded.)

DEPTH INDICATOR FOR TORPEDO BOATS.

By the English Correspondent of SCIENTIFIC AMERICAN.

AN ingenious and interesting apparatus has recently been devised for the purposes of indicating the depth of water in which a torpedo boat is traveling, by Messrs. Elliott Brothers, of Lewisham, London, based upon the results of the interesting experiments that have been carried out by Mr. Harold Yarrow, of the well-known Yarrow firm of naval shipbuilders of Poplar-on-Thames.

When the British Admiralty contracted with certain shipbuilders some four years ago for the construction of the "river class" of torpedo-boat destroyers, the feature of which was the embodiment of heavier scantlings than had been previously adopted, difficulties were experienced by the builders in connection with the speed attained by the vessels upon the trials. These craft ranged from 550 to 600 tons displacement, and the stipulated speed was 25.5 knots. Formulating the designs of this new class of destroyer with those that had been previously constructed, it was calculated that 7,000 indicated horse-power would be sufficient to produce this speed; but when the trials were commenced,



INDICATOR FOR TORPEDO BOATS INTENDED TO SHOW THE DEPTH OF WATER IN WHICH THE BOAT IS TRAVELING.

it was discovered that the possibility of attaining this contracted speed with the horse-power calculated was somewhat remote. Messrs. Yarrow & Co., who had some of the vessels in hand, carried out a series of progressive trials with the destroyer "Usk" upon the measured mile off the Maplin Sands upon the east coast near the estuary of the Thames, and the results thereby obtained demonstrated the fact that when the speed approached that guaranteed, a very small advance in speed was attained for a considerable increase in the horse-power. This peculiarity was common to all the other builders of the sister ships, with the exception of the firms who carried out their trials on the Skelmorlie measured mile. In view of the fact that the various vessels were of practically identical design, and that the depth of water on the Skelmorlie mile is about 40 fathoms, which is far in excess of that in the case of the Maplin and other trial grounds off the east coast, it was concluded that the wide variation obtained in the results was due to the differences in the depth of water in which the trial runs were made. In order to test this conclusion, Mr. Harold Yarrow embarked upon a series of prolonged experiments for the purposes of ascertaining the effect of the depth of water upon the speed of vessels, especially in regard to these torpedo-boat destroyers. The militating effects of shallow water upon the speed of vessels has frequently been investigated, especially by Sir William White, but Mr. Harold Yarrow as the result of his investigations discovered many marked peculiarities, which he communicated in an interesting and instructive paper to the British Institution of Naval Architects. For the accumulation of the data experiments were carried out with models in the testing tank simultaneously with the practical trials with a destroyer of 400 tons in a depth of 40 feet of water. These latter tests practically confirmed the results of the tank experiments, for when the steam pressure was raised from 100 pounds to 125 pounds, the increase in speed was only one-half knot; while when the pressure was raised from 125 pounds to 150 pounds, the rise in speed was no less than 5 knots. These combined experiments showed upon the carefully-prepared records that were taken, that at places the rise in speed is very small in comparison with the increase in power, while at others the rise in speed is very great in proportion to the increase in power. The diagram also showed the inclination of the vessel and the approximate height of the stern wave with reference to the stern of the boat, and one noticeable feature was that the marked increase of the inclination and stern wave occurs at those points where the power increases rapidly with but a very small acceleration in the speed.

The course selected for the runs was seven miles in length at the mouth of the Thames, the depth of water ranging from 20 feet to 100 feet. The investigations carried out were of an exhaustive character, and were made with every care. The steam pressures ranged from 40 pounds to 200 pounds, the pressures being accurately regulated by the control of the stop valves on the steam pipe, a surplus pressure being maintained in the boilers. Every minute during the runs observations were made concerning the revolutions of the engines; the inclination of the vessel read from a twenty-foot level; the height of the stern wave above or below the deck at the stern, and indicator diagrams twice on each run. The variations in the number of revolutions on each run with a constant pressure were taken as a guide to the resistance in preference to indicator diagrams, as being more positive than the latter, since any increase or reduction of resistance to the vessel would instantly show itself by a reduction in the number of revolutions.

The results attained were highly interesting in character, and exemplified in a striking manner the effects of passing through varying depths of water and their influence upon the resistance to the vessel. For instance, when working at 100 pounds pressure and at approximately 19 knots speed, the resistance in passing from a depth of 55 feet to shallow water of 24 feet was very appreciably increased, demonstrated by the fact that the revolutions fell from 278 to 250 per minute with a constant pressure of steam. Simultaneously the inclination of the boat was considerably augmented, from 2½ inch to nearly 5 inch in 20 feet, while the height of the stern wave also increased. It was pointedly shown that the inclination of the vessel taken in conjunction with the revolutions enabled a very fair estimate of the depth of the water between the limits of 20 feet and 100 feet to be obtained, and as a result of this observation Mr. Yarrow advanced the theory that this feature might be turned to valuable account for navigating purposes, for indicating the depth of water in which a vessel might be traveling at any moment. For instance, if the destroyer be running at about 19 knots and the navigating officer does not desire to approach nearer the shore than 24 feet of water, immediately the inclination rises to 4½ inches in 20 feet he knows that his limit is being approached. In determining this basis of calculation, proper data concerning the characteristics of each vessel must be obtained, and then the depth of water under the boat at any time can be approximately calculated.

The indicator shown in the accompanying illustration is based upon the hypotheses advanced by Mr. Yarrow as the result of his investigations, and was recently exhibited before the Institution of Civil Engineers, where it aroused wide interest. The device consists of six spirit levels hinged, and which can be separately set and clamped to any small inclination. They are carried in position by two vertical pillars as shown, and the latter are attached to a hinged base, the top of which can be set level by the operation of an adjusting screw, there being a fixed spirit level to indicate when the hinged base is horizontal.

The operation of the indicator is very simple. It is placed in a convenient position upon the navigating bridge, and when the vessel is at rest set level. As the inclination of the vessel for each speed corresponds to the depth of water, such as, for instance, at a speed of 16 knots at a depth of 30 feet, the inclination is 1½ inches in 20 feet, and for 18 knots an inclination of 2¼ inches in 20 feet, etc. No. 1 hinged level is set to an inclination of 1½ inches in 20 feet. If the boat is traveling at 16 knots, when the bubble passes to the other side of the level the officer can see that the depth of water is about 30 feet. No. 2 hinged level is similarly set to an inclination of 2¼ inches, corresponding to 20 feet of water, and if the boat is running at 18 knots when the bubble travels to the other side of the level, the depth of water is 3 feet, and so on for higher speeds and other levels.

In order to ascertain the inclination at which to set the levels, experiments with one boat of each type would have to be carried out, but once the inclinations corresponding to the various speeds for a given depth are ascertained, the accuracy of the instrument is not impaired by any practical alteration in the trim due to lading. Any change of trim that may be necessary at a later date, due to a different lading, can be allowed for and adjusted as required, so that the base of the instrument is always level. The speed of the vessel can be determined with sufficient accuracy for the operation of the instrument from the revolutions of the engines.

The utility of this instrument from a navigation point of view is apparent, since the officer in charge can ascertain at any moment when the vessel is approaching shallow water, without having recourse to sounding or other means of determining his position. Especially useful would it prove in foggy weather, or when progressing along an unknown coast. In rough weather, owing to the pitching of the vessel, the instrument is naturally, from the nature of its design, not available; but on the other hand, owing to the fact that in foggy weather the water is generally calm, its utility is readily recognizable.

[Concluded from SUPPLEMENT No. 1603, page 25689.]

THE ART OF INVENTING.—II.*

By EDWIN J. PRINDLE, of the New York Bar.

A MOST interesting example of the evolution of an invention is that of the cord-knotter of the self-binding harvester. The problem here was to devise a mechanism which would take the place of the human hands in tying a knot in a cord whose ends had mechanically been brought together around a bundle of grain.

The first step was to select a knot which could be tied by the simplest motions. The knot which the inventor selected is that shown in Fig. 10, and is a form of bow-knot.

The problem was to find how this knot could be tied with the smallest number of fingers, making the smallest number of simple movements. As anyone would ordinarily tie even this simple knot, the movements would be so numerous and complex as to seem impossible of performance by mechanism. The inventor, by study of his problem, found that this knot could be tied by the use of only two fingers of one hand, and by very simple movements. The knot will best be understood by following the motions of these fingers in tying the knot. Using the first and second fingers of the right hand, they are first swept outward and backward in a circular path against the two strands of the cord to be tied, as shown in Fig. 11.

The fingers continue in their circular motion backward, so that the strands of the cord are wrapped around these fingers, as shown in Fig. 12.

Continuing their circular motion, the fingers approach the strands of the cord between the twisted portion and a part of the machine which holds the ends of the cord, and the fingers spread apart as shown in Fig. 13, so that they can pass over and grasp the strands thus approached, as shown in Fig. 14.

The fingers then draw back through the loop which has been formed about them, the fingers holding the grasped portion of the strands, as shown in Fig. 15.

The knot is finished by the completion of the retracting movement of the fingers through the loop, thus forming the bow of the knot as shown in Fig. 16.

The inventor found that one finger could have a purely rotary movement, as if it were fixed on the arm and unable to move independently of the arm, and the movement being as if the arm rotated like a shaft, but the second finger must be further capable of moving toward and from the first finger to perform the opening movement of Fig. 13, and the closing movement of Fig. 14 by which it grasps the cord. The inventor accordingly, from his exhaustive analysis of his problem, and his invention or discovery of the proper finger motions, had further only to devise the very simple mechanical device illustrated in Fig. 17 to replace his fingers.

The index finger of the hand is represented by the finger *S*, which is integral with the shaft *V*. The second finger of the hand is represented by the finger *U*, which is pivoted to the first finger by the pin *s*. The grasping movement of the finger *U* is accomplished by a spring *V'* bearing on the shank *U'*, and its opening movement is caused by the travel of an anti-friction roll *U''*, on the rear end of the pivoted finger, over a cam *V''*, on the bearing of the shaft. The shaft is rotated by the turning of a bevel pinion *W* on the shaft through the action of an intermittent gear. The necessity of drawing the fingers backward to accomplish the movement between Figs. 14 and 16 was avoided by causing the tied bundle to have a motion away from the fingers as it is expelled from the machine, the relative motion between the fingers and the knot being the same as if the fingers drew back.

Thus the accomplishment of a seemingly almost impossible function was rendered mechanically simple

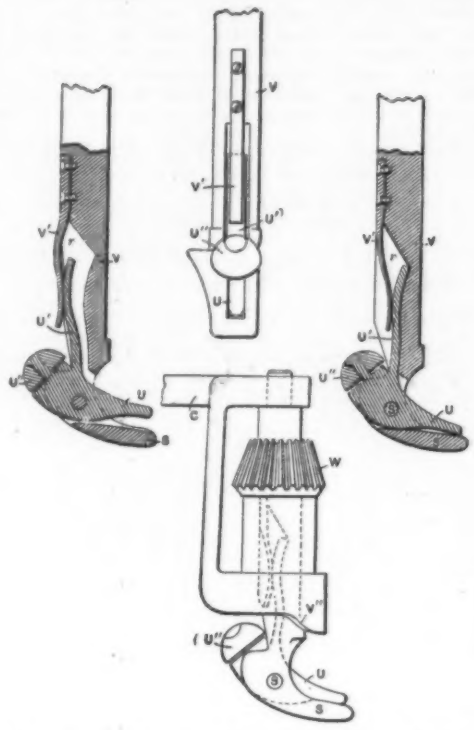


FIG. 17.—THE ESSENTIAL PARTS OF THE CORD-KNOTTER.

by an evolution from the human hand, after an exhaustive and ingenious analysis of the conditions involved.

It will be seen from the examples I have given that the constructive part of inventing consists of evolution, and it is the association of previously known elements in new relations (using the term elements in its broadest sense). The results of such new association may, themselves, be treated as elements of the next stage of development, but in the last analysis nothing is invented or created absolutely out of nothing.

It must also be apparent, that pure reason and method, while not taking the place of the inventive faculty can clear the way for the exercise of that faculty and very greatly reduce the demands upon it.

Where it is desired to make a broadly new invention on fundamentally different lines from those before—having first studied the art to find the results needed, the qualities of the material or other absolutely controlling conditions should be exhaustively considered; but at the time of making the inventive effort, the details should be dismissed from the mind of how results already obtained in the art were gotten. One should endeavor to conceive how he would accomplish the desired result if he were attempting the problem before any one else had ever solved it. In other words, he should endeavor to provide himself with the idea elements on which the imagination will operate, but to dismiss from his mind as much as possible the old ways in which these elements have been associated, and thus leave his imagination free to associate them in original and, as to be hoped, better relations than before. He should invent all the means he can possibly invent to accomplish the desired result, and should then, before experimenting, go to the art to see whether or not these means have before been invented. He would probably find that some of the elements, at least, have been better worked out than he has worked them out. Of course, mechanical dictionaries, and other sources of mechanical elements and movements will be found useful in arriving at means for accomplishing certain of the motions, if the invention be a machine. Many important inventions have been made by persons whose occupation is wholly disconnected with the art in which they are inventing, because their minds were not prejudiced by what had already been done. While such an effort is likely to possess more originality than that on the part of a person in the art, there is, of course, less probability of its being thoroughly practical. The mind well stored with the old ways of solving the problem will, of course, be less likely to repeat any of the mistakes of the earlier inventors, but it will also not be as apt to strike out on distinctly original lines. It is so full, already, of the old forms of association of the elements as to be less likely to think of associating them in broadly new relations.

Nothing should be considered impossible until it has been conclusively worked out or tried by experiments which leave no room for doubt. It is no sufficient reason for believing a thing won't work because immemorial tradition, or those skilled in the art, say it will not work. Many an important improvement has been condemned as impracticable, by those in the art, before it has been tried.

A conception which an inventor has been striving for unsuccessfully will sometimes come to him at a time of unaccustomed mental stimulation. The slight stimulation of the movement of a train of cars, and the sound of music, have been known to produce this effect. The sub-conscious mind, after having been prepared by a full consideration of the problem to be solved, will sometimes solve the problem without conscious effort, on the part of the inventor.

In inventing a machine to operate upon any given material, the logical way is to work from the tool to the power. The tool or tools should first be invented, and the motions determined which are to be given to them. The proper gearing or parts to produce from the power each motion for each tool should then be invented. It should then be considered if parts of each train of gearing cannot be combined, so as to make one part do the work of a part in each train; in short, to reduce the machine to its lowest terms. Occasionally a mechanism will be invented which is exceedingly ingenious, but which it is afterward seen how to simplify, greatly at the expense of its apparent ingenuity. This simplification will be at the sacrifice of the pride of the inventor, but such considerations as cheapness, durability, and certainty of action leave no choice in the matter. It will sometimes be found that a single part can be made to actuate several parts, by the interposition of elements which reverse the motion taken from such part, or which take only a component of the motion of such part, or the resultant of the motion of such part and some other part. Where a machine involves the conjoint action of several forces, it

FIG. 10. FIG. 11. FIG. 12. FIG. 13.

FIG. 14. FIG. 16. FIG. 15.

* Read before the American Institute of Electrical Engineers.

can be more thoroughly studied, if it is found there are positions of the machine in which one force or motion only is in operation, the effect of the others in such position being eliminated, and thus the elements making up the resultant effect can be intelligently controlled.

The drawing board can be made a great source of economy in producing inventions. If the three principal views of all the essentially different positions of the parts of a machine are drawn, it will often be found that defects will be brought to light which would not otherwise have been observed until the machine was put into the metal.

It is desirable to see the whole invention clearly in the mind before beginning to draw, but if that cannot be done, it is often of great assistance to draw what can be seen, and the clearer perception given by the study of the parts already drawn, assists the mind in the conception of the remaining parts.

If the improvement which it is sought to make is a process, it should first be considered whether any radically different process can be conceived of, and if so, whether or not it is better than the old process, and the reason for its defects, and whether it is possible to cure those defects. If the old process appears to be in the right general direction, it should be considered whether one of the old steps cannot with advantage be replaced by a new one, or whether the order of performing the steps cannot be changed to advantage. I have in mind one process in which a reversal of the order of steps resulted in giving the product certain desirable qualities which had before been sought for, but could not be obtained.

It is sometimes desirable not only to invent a good process of producing a product, but to control all feasible processes of producing the product. Such a case occurred where the product itself had been patented, and it was desirable to extend the monopoly beyond the time when the patent on the product should expire. There were two steps or operations which were essential to the production of the product, and the inventor, by reference to permutations, saw that there were but three orders in which those steps could be performed; first, the order A-B, then the order B-A, and then both steps together. The order A-B was the old order, which did not produce an article having the desired qualities. The inventor, therefore, proceeded to invent ways by which they could be performed together, and then by which they could be performed in the reverse order, and the patenting such two processes would cover generically all possible ways of making the article and secure the desired result of putting himself in position to control the monopoly after the patent on the article had expired, because no one could make the article without using one of his two processes.

In inventing compositions of matter there is one inventor who, if he is seeking for a certain result, will take a chemical dictionary and make every possible combination of every substance that could by any possibility be an ingredient of that which he desires to produce. It is as if he were seeking to locate a vein of mineral in a given territory, and, instead of observing the geographical and geological formation, and thus seeking to arrive at the most probable location of the vein, he should dig up every foot of earth throughout the whole territory, in order finally to locate the vein. This method is exceedingly exhaustive, but does not appeal to one as involving much exercise of the inventive faculties.

Inventing has become so much of a science, that if one is willing to spend sufficient time and money to enable a competent corps of inventors to go at the matter exhaustively, almost any possible invention involving but a reasonable advance in the art can be perfected.

A NOVEL WIND SHIELD.

By JOSEPH EYSSÉRIC.

IT has long been observed that when the wind strikes an awning, the side of a ship, or a corniced wall of suitable form, the following peculiar phenomenon may occur in certain conditions of wind velocity and relative direction. The current of air rises above the obstacle, leaving behind and below it a region of calm which extends above the top of the obstacle. An observer placed behind the obstacle can therefore see over it, and at the same time remain completely sheltered from the wind.

In most cases, however, a slight and apparently insignificant change in the conditions suffices to destroy this peculiar effect. It becomes of interest, therefore, to discover how the effect is produced, to determine the most effective form of a wind shield of this character, and the minimum area compatible with satisfactory protection.

Such wind shields are particularly useful in cases where transparent shields are inadmissible or dangerous, as on the bridge of a ship, where dew would soon make a glass shield opaque, in railway signal towers and on locomotives, and especially in automobiles, where glass gives rise to reflections and tremors which interfere with the view, besides being very dangerous on account of its liability to fracture.

I have experimented with single surfaces of various areas, curvatures, and inclinations to the wind, and also with surfaces combined in various ways. The shields thus formed are mounted on a platform about six feet high, freely exposed to the wind (Fig. 1). The velocities of the wind and of the currents deflected by the shield were measured with a small Richard anemometer.

The following experiment will serve to give an idea of the action of the apparatus (Fig. 2). The shield is composed of two parts, represented in profile by *AB* and *Ab*, each of which may be inclined at any angle. Both are slightly curved and their concave faces are in front. The lower surface, *AB*, is much larger than the other. The wind striking this compound shield is deflected and guided by it and the derived current leaves the shield in a direction and with a force dependent on the position and curvature of the upper segment

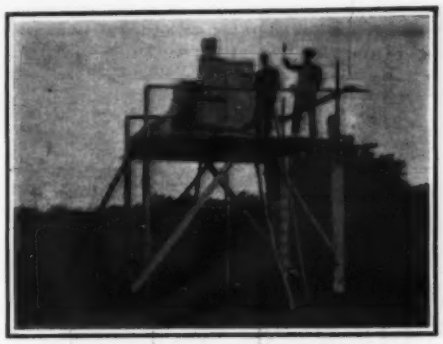


FIG. 1.—EXPERIMENTS WITH WIND SHIELD MOUNTED ON STATIONARY PLATFORM.

Measuring velocity of wind (blowing from left to right) with a hand anemometer.

Ab, which are factors of the highest importance. After leaving the point *b* the deflected current continues to move upward, but with constantly decreasing force, through a horizontal free wind of uniform velocity. The result is that the derived current is bent backward in a curve, *brC*, which forms the boundary of a calm region extending above the level of *b*. Consequently, an eye placed at *O* can look forward and even obliquely downward along the line *Ob*, thus seeing clearly in front of the apparatus, while it remains sheltered from the wind.

The calm region is not defined with perfect sharpness, but is separated from the region exposed to the full force of the wind by a thin sheet of air more or less agitated. Nevertheless, the boundary is sufficiently well defined to permit approximate measurement of a series of abscisses (*bs*, etc.) and their corresponding

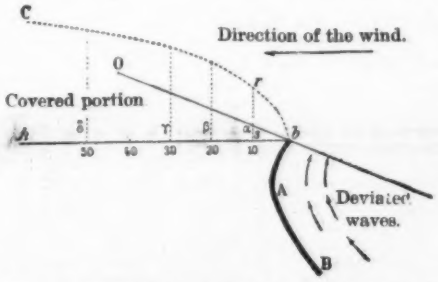


FIG. 2.—PROFILES OF TWO-PART SHIELD AND SHELTERED REGION.

Distances marked in centimeters. Only the upper part of the main shield, A B, is shown.

ordinates (*rs*, etc.). The bounding curve, *brC*, is thus found to be, very nearly, a parabola.

The problem of the construction of the shield is thus reduced to obtaining a limiting parabola with the greatest possible parameter, or breadth, by the use of deflecting surfaces as small as possible, for the curve varies with the dimensions, curvatures, and inclination of the surfaces. The conclusion drawn from all the experiments is that the most effective arrangement of the elements of the shield is the one shown in profile in Fig. 3. The principal element, *AB*, is slightly concave and fixed in position, with its chord inclined about 45 degrees to the horizontal. To the upper edge of this the small curved element *Ab* is attached by hinges, so that its inclination may be varied. For moderate velocities of the wind (or the vehicle) this movable part should be inclined sharply forward; for

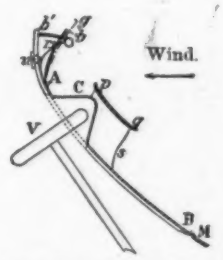


FIG. 3.—PROFILE OF THREE-PART SHIELD ADAPTED TO AN AUTOMOBILE.

very great speeds it should be more nearly parallel with the fixed part. This small movable element is the most delicate portion of the apparatus. Finally, the effectiveness of the shield appears to be increased by fixing a small auxiliary surface, *pg*, in front of *AB* and parallel to it. This apparatus has been found to work well with winds of from 10 feet to more than 50 feet per second.

The vertical velocity of the deflected current was studied by placing the anemometer horizontally at various distances in front of the shield (1, Fig. 4). The lengths of the vertical arrows represent the vertical velocities of the deflected current at three points for three different wind velocities (the latter represented by the horizontal arrows) and the maximum velocities are given in figures (in meters per second). The mean velocity of the deflected current measured parallel to the shield was about 9-10 of the velocity of the wind. The form and arrangement of the deflecting

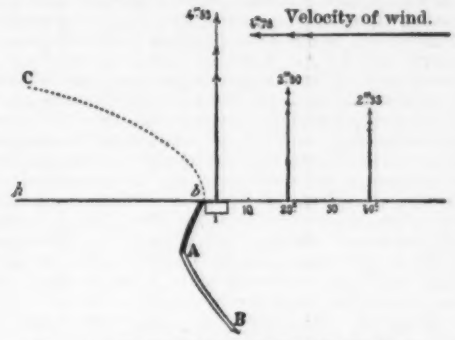


FIG. 4.—VERTICAL COMPONENTS OF VELOCITIES OF DEFLECTED CURRENTS.

Velocities in meters per second. Distances in centimeters.

surfaces were based on the results of experiments of this sort.

When applied to the automobile the wind shield must be small and close to the driver in order to conceal from him as little as possible of the vehicle. Hence it becomes necessary to allow the steering wheel (*V*, Fig. 3) to pierce the main shield, *A B*, and to cover the opening with a hood, *C*. In this case it is advantageous to guide the deflected current over and around the hood by the small auxiliary shield *p g*, which, in addition to producing the desired effect, raises the upper limit of the protected region. The auxiliary must be parallel to the main shield. Though, at first sight, it might appear best to arrange these two surfaces so that they would form a sort of funnel with its mouth directed toward the small adjustable shield above, experience has shown that any considerable deviation from parallelism almost completely destroys

FIG. 5.—AUTOMOBILE WITH WIND SHIELD.

the effect of the apparatus. This apparent paradox, however, is explained by the study of the deflected current and by other considerations. The automobile shield, represented in profile in Fig. 3, is shown in position in Fig. 5. The heads of the passengers are well above the shield, which protects both seats. Of course, it is not proposed to eliminate every breath of air, but merely to avoid head winds and the wind due to speed sufficiently to do away with goggles as well

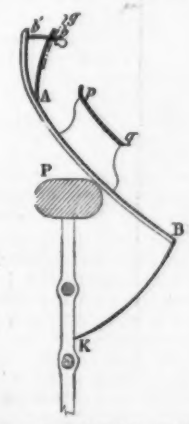


FIG. 6.—PROFILE OF SHIELD FOR USE ON SHIPBOARD.

as the glass front. The movable element *A b* (Fig. 3) is adjusted automatically according to the force of the wind by means of the springs *r*, which are regulated by the screw *v*. This part may be made of celluloid or of insoluble gelatine to enable the front wheels of a short car to be seen through it and its height may be made variable by making it double, like the sashes of a window. Fig. 6 shows the wind shield applied to the bridge or lookout post of a vessel. In addition to the

three parts described above there is an apron *B K* to prevent the wind from blowing under the shield.

This wind shield is also very well adapted for use in motor boats.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from La Science au XXme Siècle.

BRICKWORK TESTS.

No materials employed in building construction are more familiar than bricks and mortar, and yet there are few whose physical properties have been less studied. The lack of reliable data as to the strength of brickwork is even more marked. To some extent these anomalies are readily explained.

The strength of bricks depends upon the chemical composition of the clay from which they are made, upon the preparation of the clay, and upon the extent of the changes effected by the process of burning. Thus, pure clays contract considerably in burning and do not vitrify, with the result that the bricks are not durable. Sand has the effect of reducing contraction and of promoting vitrification. Oxide of iron is a useful constituent which by acting as a flux encourages fusion of the silica, and gives hardness and strength to the product. Sulphate of lime by rendering the clay too fusible leads to distortion in the kiln, and carbonate of lime being decomposed yields quicklime which, becoming slaked by the absorption of moisture, causes partial disintegration. Free silica is beneficial in moderate quantities, but in excessive proportions renders bricks brittle. In addition to the effects of different constituents, the processes of manufacture have an important bearing upon the strength of bricks, and the influence of burning is so varfable that differences up to 100 per cent may exist between two samples taken from the same kiln.

Sufficient experiments have been made to indicate the compressive strength of the principal varieties of brick, but only in a general way. The lack of more definite information than that available may be attributed in great measure to the fact that, so far as concerns the bulk of the brick buildings erected in London and the chief centers of population in Great Britain, architects have no occasion to calculate the strength of the chief material used. Building regulations provide for certain thicknesses of brickwork, and the weakest bricks afford ample strength. This may account for the feeble interest displayed with regard to brick tests. It is true that bricks are used to some extent in engineering structures to which stereotyped laws do not apply. For such works data are certainly necessary, and are usually obtained by the designer for the particular description of brick which it is intended to employ.

Again, mortar is looked upon as a material intended merely to keep the bricks in place, and not to impart transverse strength to the construction. Moreover, lime mortar hardens so slowly that interior portions not exposed to the air may not set for many years. Consequently little or no demand has arisen for data concerning the strength of mortar used in ordinary building construction.

Reliable information as to the strength of brickwork is still more lacking than data relative to its constituent parts. The extent of the knowledge to be extracted from Rankine's "Civil Engineering" is represented by this sentence: "A small pillar of brickwork, made of bricks of this quality laid in cement, should require from 800 to 1,000 pounds on the square inch to crush it." By "this quality" is meant bricks which, when set on end in a hydraulic press, cannot be crushed under a smaller pressure than 1,100 pounds per square inch. Thus, according to Rankine, a pier built of bricks having the ultimate crushing strength of 71 tons per square foot should not fail under loads less than from 51 tons to 64 tons per square foot. This implies that the strength of a brick pier in terms of the strength of a single brick is represented by a ratio ranging from 0.72 to 0.9. But as the strength of brick tested in its normal position is about twice as much as when tested on end, the ratio ought to be stated at between 0.36 and 0.45 approximately. Rankine's information does not extend to brickwork in lime mortar, and his statements are altogether too vague to be of the least practical use.

Results obtained by Dr. Böhme on brick cubes 10 inches by 10 inches by 9.5 inches are summarized in Prof. Unwin's work on "The Testing of Materials of Construction." Two kinds of brick were chosen for these experiments: Beneckendorfer brick, with the crushing strength of 263.2 tons per square foot, and Hertzfelder brick, with the crushing strength of 160.9 tons per square foot. The records are of little use except to throw light upon the influence of different mixtures of mortar upon the strength ratio of brickwork to single bricks. Taking the highest and lowest figures, the ratios were 0.64 for 1 : 3 cement mortar, and 0.44 for 1 : 2 lime mortar.

From an interesting series of tests conducted at the School of Practical Science, Toronto, on brick piers about 2 feet high by 9 inches square, we select the above results for comparison. The strengths of the mortars were: Lime mortar (1 part of lime to 2 parts of sand) 65 pounds per square inch, and cement mortar (1 part of Portland cement to 3 parts of sand) 1,352 pounds per square inch, the age of the mortar and piers being 10 to 11 weeks.

Brick.	Average Crushing Strength.		Ratio of Strength, Pier to Brick.	
	Lime Mortar, Tons per Sq. Ft.	Cement Mortar, Tons per Sq. Ft.	Lime Mortar.	Cement Mortar.
Yorkville 1st.....	38 6	76.5	0.123	0.356
Yorkvil e 2d.....	28.2	73.3	0 141	0.366
Humber 2d	31.0	81.4	0.177	0.464
Kingston-road 3d...	39.7	61.3	0.278	0 502
Carleton clinker..	43.8	178.4	0.121	0.476

Some tests conducted at Watertown Arsenal* upon brick piers, 12 inches square, and from 1 foot 4 inches to 10 feet high, afford more striking testimony as to the vagaries of experimental results. From these records we quote the following as most applicable in this country:

Mortar.	Ultimate Strength of the Pier, Tons per Sq. Foot.	Compressive Strength of the Mortar, Tons per Sq. Foot.	Mean Ratio of Strength, Pier to Brick.
Lime 1, sand 3.....	97	0.8	0.101
Lime 1, sand 3, cement 0.5..	91	1.23	0 094
Cement 1, sand 2.....	184	3.5	0.179
Neat cement	153	22.4	0.158

It should be remarked that the very small values of the ratio of strength is due to the fact that the average crushing strength of the bricks tested flat was nearly 965 tons per square foot. Notwithstanding the inconsistency of the relations between the strength of the brickwork and the mortar in the Watertown tests, it is clear from the two preceding sets of results that the strength of brickwork depends mainly upon the strength of the mortar. This is also shown by a series of tests conducted at Watertown Arsenal by the American Society of Civil Engineers in 1887-8. The investigation was made upon piers of various dimensions built of different qualities of brick, some laid in 1 : 3 lime mortar, and others in cement mortar of different proportions. Examination of the results shows that the piers built with cement mortar possessed an average strength equal to about 1½ times that of the piers built with lime mortar. For a useful summary of the results the reader is referred to the "Report on Brickwork Tests," recently issued by the Royal Institute of British Architects.†

We have reserved mention of this valuable publication until the present stage with the object of showing how great was the want for reliable and consistent information as to the strength of brickwork. Many of our readers have already had the opportunity of studying the report in the Transactions of the Institute.

The inquiry was undertaken by a sub-committee of the Science Standing Committee in the year 1893. Three series of tests were conducted, the first two upon thirty-eight piers all 6 feet high by 18 inches square, and the third upon twenty lengths of brick walling 6 feet high by 27 inches long by 18 inches thick.

The materials employed in the first and second series are given below, together with the strength of the bricks and mortar. It should be stated that the mortars tested were made with "Standard" sand, and not with the sand used in building the piers. When made with the latter the strengths would probably not be more than half the values given below:

Brick.	Mean Crushing Strength.		
	Brick, Tons per Sq. Ft.	Lime Mortar 1 : 2, Age 24 Weeks, Tons per Sq. Ft.	Cement Mortar 1 : 4, Age 24 Weeks, Tons per Sq. Ft.
London stock.....	84.27	15.72	56.15
Gault.....	182.2	15 72	56.15
Leicester red (half brick).....	382.1	15 72	56.15
Leicester red (whole brick).....	509.0	15.72	56 15
Staffordshire blue (half brick)	701.1	15 72	56.15
Staffordshire blue (whole brick)	935.0	15.72	56.15

The Staffordshire bricks were so strong that they could not be crushed in the testing machine available. Consequently they were cut in half and tested as half bricks. We cannot see any reason why the same course should not have been followed in the case of Leicester red bricks, and it is to be regretted that the actual strength of these was not determined. As a separate series of tests suggested that the resistance per square foot of whole bricks was about one-third more than that of half bricks, we have inserted values on this basis in the foregoing table.

The piers were built in 1895 for the first two series of tests, sixteen piers for Series I., and sixteen piers for Series II. Owing to the fact that the bricklayers substituted London stocks as closers in the Leicester red and Staffordshire blue brick piers, some piers in the first set were rendered practically useless. Hence six duplicates, constituting Series I*a*, were built and tested with the piers of Series II. Subsequently, at the suggestion of Prof. Unwin, a pier was built of bricks simply laid in sand.

Those piers tested in the first series had the average age of about nineteen weeks; in the second series proper they were about forty-five weeks old, in Series I*a* nearly thirteen weeks old, and the pier in sand was crushed during the day on which it was built.

Summarizing the results of Series I. and II. for comparison with those previously quoted in this article, we have the following record, the ratio of strength being calculated for whole, and not for half bricks as in the report:

Brick.	Mean Crushing Strength.		Ratio of Strength, Pier to Brick.	
	Lime Mortar, Tons per Sq. Ft.	Cement Mortar, Tons per Sq. Ft.	Lime Mortar.	Cement Mortar.
London Stock.....	11.83	17.29	0.14	0.20
Gault	21.76	23.88	0.12	0.13
Leicester red.	32.43	54.45	0.06	0.10
Staffordshire blue ..	73.98	77.64	0.08	0.08

These figures demonstrate the advantage of the stronger cement, but not in a uniform manner. Even in comparing the ratios on lines 1 and 3 of the table with the relative resistance of lime and cement mortar, it is evident that the increased strength due to cement mortar is far from being proportionate to the higher crushing strength of that material when tested separately.

The explanation is to be found in the behavior of the piers while under compression. We are told in the report that the successively developed evidences of strain were internal cracking sounds, the squeezing of mortar from joints, the cracking of single bricks under unequal strains, the appearance of cracks indicating final lines of rupture, bulging of the brickwork, and, finally, collapse of the structure. The same phenomena were exhibited in both Series I. and II., and it was remarked that the vertical line of joints formed by the closers was always a plane of weakness where serious cracks first showed themselves. The result given by the pier built with dry sand shows that it carried 15 tons per square foot, or approximately half as much as other piers laid in lime mortar which had been allowed to harden for about twenty-two weeks and forty-six weeks. Examination of the diagram representing this experiment gives a clue to the manner in which brickwork is likely to fail if exposed to additional loads after the cohesion of the mortar has been destroyed.

For the purpose of Series III. Fletton and Staffordshire blue bricks were used, the average crushing strengths being 220.85 tons and 779.6 tons per square foot respectively. As the Staffordshire bricks could not be tested whole, the actual crushing strength was probably about 1,040 tons per square foot. No comparative tests of the lime and cement mortar are published, a rather unfortunate omission.

The elements of uncertainty mentioned above clearly take away some of the value from the third series of tests. It should be noted that the brickwork, being built with a wall bond, was free from the vertical joint occurring at the angles of the 18-inch piers, and that all the specimens were about twenty-two weeks old at the time of test. The following table gives the average results, and the ratios of strength calculated for whole bricks as before:

Brick.	Average Crushing Strength.		Ratio of Strength, Pier to Brick.	
	Lime Mortar, Tons per Sq. Ft.	Cement Mortar, Tons per Sq. Ft.	Lime Mortar.	Cement Mortar.
London Stock.....	18.64	39.29	0.22	0.47
Fletton.....	30.68	56.25	0.14	0.28
Gault.	31.14	51.34	0.17	0.28
Leicester red.	45.36	83.56	0.09	0.16
Staffordshire blue. ..	114.34	135.43	0.12	0.14

While the report contains much valuable information, and most interesting details concerning the mode in which the failure of the different piers and wall sections occurred, the records are not so complete in some respects as could be desired.

Being dependent upon the generosity of Sir William Arrol for the 100-ton testing machine lent for the purposes of the investigation, the committee cannot be blamed for the circumstance that some of the bricks could not be tested whole. Scientific bodies in the United States are far more favored in this respect than our own institutions, for they have the privilege of using the 500-ton testing machine at Watertown Arsenal—one more evidence of the intelligent interest taken by the United States government in scientific research.

There could not be any valid reason, however, for the omission to prepare samples of the lime and cement mortar with the sand actually employed in building the piers. It is said in the report that "the quantity of sand was not sufficient for making more than a few briquettes, and therefore it was decided to use for most of the briquettes the standard washed and sifted sand which has been generally adopted for cement tests, and which is obtained from Leighton Buzzard." Sand is not a very expensive commodity, and the neglect to furnish it in sufficient quantity for the mortar tests could only arise from want of forethought. The result is that no direct comparison can be made of the strength of the piers in terms of the strength of the mortar.

A still more serious fault is that arising from the inefficient supervision exercised over the work of the bricklayers employed to build the first and second series of piers. As we have already pointed out, six of the piers were rendered practically useless by the reprehensible action of the workmen, and there is good reason for inferring that the accuracy of the remaining results was appreciably affected by variations of workmanship.

* "Report on Tests Watertown Arsenal, U. S. A., 1889–4," pp. 69–122

† "Report on Brickwork Tests." London: The Royal Institute of British Architects. 1906.

The walls of Series III., and the six substituted piers, constituting Series Ia, were built under the direction of a competent clerk of works, who certainly ought to have been engaged at the start. As this somewhat obvious precaution was neglected, the original intention of the committee has not been fully realized. The objects, as we understand them, were (1) to obtain figures representing the strength of piers each built of a specified variety of brick, with a uniform quality of workmanship and tested in two groups at the ages of twenty-two weeks and forty-six weeks respectively; and (2) to make a comparison of the values with those obtained from similar piers built with a wall bond instead of the usual pier bond. These objects have been defeated in some measure by the introduction of London stock closers into the Leicestershire red and Staffordshire blue brick piers, and probably by variations of workmanship among the piers of Series I. and II. Even if such variation did not take place, the quality of workmanship in Series I. and II. as a whole differed very much from the workmanship of Series III., and it must also be remembered that some of the bricks used for the last series were of different quality from those in the two previous series. Hence discrepancies arose of the very identical kind which the Science Standing Committee of the Institute desired to avoid. Further discrepancy was due to the superior quality of the six substituted piers (Series Ia) the tests suggesting the paradox that brickwork is weaker at the age of ten months than at the age of four months. Admitting that architects and building contractors have ample reason to be grateful for the useful information contained in the report, it is impossible to avoid the feeling of regret that unpremeditated variations were allowed to disturb the complete consistency of the data. We must, however, express satisfaction that the report states without reserve all the conditions attending the tests, and contains the fullest possible particulars relative to the behavior of each pier and wall when under test. Under the circumstances, the best way to consider the data is under three separate categories: (*a*) Series I. and II., representing average building construction at different ages; (*b*) Series Ia, indicating the greater strength of superior workmanship even when comparatively new; and (*c*) Series III., showing the combined, but not the separate, merits of superior workmanship and of the wall bond as compared with the pier bond used in the two other series.—The Builder.

LIGHTNING CONDUCTORS.

EVER since Franklin devised the lightning rod it has been a subject of doubt and discussion. In early days there were those who held it to be an impious interference with Heaven's wrath, evil in principle and doubly sacrilegious if successful. In this connection it is interesting to note that Robespierre as a fledgling lawyer successfully defended a client haled to court by the ecclesiastic powers on the charge of sacrilege from having erected a lightning rod. Others have doubted its efficacy altogether and still others have treated it with superstitious reverence, decking it with platinum tips and gilded balls and insulating it as carefully as if it were an electroscope, and they consecrated priests of radium. As in most cases, truth is found along the middle course. A lightning discharge is fundamentally a condenser discharge in which clouds and earth are the electrodes and half a mile of air more or less the dielectric. More rarely the discharge is betweer cloud and cloud, but however the discharge occurs, it is essentially a condenser discharge. It differs from the discharge of a Leyden jar, however, by reason of the enormous magnitude of the charges involved. As is well known, a Leyden jar discharge is oscillatory in character, the first rush of current reversing and dying away in diminishing waves. But the period of the oscillation is determined by the capacity of the jar, and when one is dealing with the prodigious charges of a cloud and the subjacent earth, the current is practically one tremendous rush, the reversal being damped out of existence. Now and then, especially between adjacent clouds, the capacity may be large enough and the resistance small enough to give oscillations, but this case is exceptional.

Given a heavily charged cloud overhead and the question of when the discharge will break through the dielectric is all-important and indeterminate. If the lower electrode, that is, the earth, bears conspicuous projections which are conductors as compared with air, the break is likely to take place at one of these points. As the projection becomes a larger and larger fraction of the total thickness of dielectric, that is, of the distance between earth and cloud, the chance of a local break increases. For example, the Washington Monument would always span a material fraction of this distance and be frequently hit, as experience has shown. Tall buildings, steeples and chimneys are, therefore, danger spots, as are high ridges across the path of a storm, especially when crowned with trees. Buildings wet with rain are poor conductors as compared with metals, but good ones as compared with air, so that they are apt to locate the point of puncture. Buildings very low as compared with cloud heights, say twenty or thirty feet in one or two thousand, do not sensibly weaken the insulation of the great air-gap. The quantity of a lightning discharge is at times enormous, the equivalent of many thousand amperes, and as the discharge takes place in a fraction of a second, the concentration of energy is very great and something has to give way. The principle of the lightning rod is locally to weaken the dielectric by putting a conductor far enough above buildings to determine the place of a threatened discharge and to carry it to earth without destructive results. Hence, the fundamental thing is to carry a conductor high enough to be well above any object to be protected and to make it big enough to stand the discharge without injury.

Very high structures are in these days often fairly good conductors, and it is seldom that a skyscraper is injured by lightning unless by the destruction of a flagstaff, the great metallic frame preventing any dangerous concentration of energy. Steel and masonry combinations in general tend to protect themselves. High chimneys, however, are apt to be injured at times and in these structures the main thing is to carry a rod high enough to deflect to itself the most of the energy. Iron ladders often serve the purpose, with an upper rod perhaps rising no higher than a diameter of the stack. One of the interesting problems is the protection of reinforced-concrete structures. There has hardly yet been experience enough with such to determine how much the reinforcing can carry lightning without injury, and the side of safety would seem to lie on enough localized metal to take care of the major part of the energy. If a special lightning conductor is used at all, it should be thoroughly well grounded, and of good cross-section, but insulated only by being carried slightly away from the wall in order to lessen the chance of scarring it locally. Fanciful cross-sections and elaborate terminal fixtures are of no consequence whatever, nor is the material of any particular moment, any metal being enough better than wood or masonry to serve the purpose. Iron serves as well as copper if in a liberal rod, say three-quarters of an inch to an inch in diameter. Possibly carefully pointed rods, if high enough and numerous enough, would tend to prevent the accumulation of charge above them and thus render lightning infrequent, but practically rods serve merely to determine the path of the discharge which from natural causes would take place in the vicinity, and thus to shield the building to which they are attached. The chief thing is to get well up above the structure, unless the framework is part of the conducting system, and to get the foot of the conductor into good wet earth. In high isolated buildings the rod plays a more useful part than elsewhere merely because such buildings are natural danger points. In the open country trees are the most efficient kind of conductors because they are sure to be well grounded.

Summing up the entire matter from a practical standpoint, any object that rises considerably above the general level of its surroundings is by this fact in more than usual danger from lightning and should be protected by conductors. The point or points should rise above the top of the structure at least a radius of the area designed to be protected. Buildings with grounded roofs or steel frames are themselves so good conductors that special additional conductors do not give enough extra conductivity to determine the discharge successfully. The material and shape of the lightning conductor makes little or no difference, so that tubes, straps and twisted conductors have only a fanciful value. An ordinarily heavy lightning discharge involves so great capacity that it is practically non-oscillatory and the chief point is to give the conductor cross-section enough to prevent its fusing and render it a first-class path to earth. The last condition must be completed by getting down to wet earth and setting the rod in a mass of damp coke or charcoal or attaching a ground plate. Where house rain leaders connect to dry wells, an ideal ground can be obtained by attaching the lightning conductor to a coil of wire or metal plate at the bottom of a well. The supports require no insulating sleeves, but should be carried a few inches from the building merely to prevent incidental damage. Lightning indulges at times in strange freaks and even the best rods may fail when used on bulky buildings which offer a large surface at an elevation nearly as great as the rod. The path of the air discharge is so erratic that it cannot be depended upon to take the nearest way. But in case of steeples, chimneys and the like, a substantial and well-grounded rod is very generally effective, especially if its terminal is well above the top.—The Engineering Record.

CONTEMPORARY ELECTRICAL SCIENCE.*

THE POSITIVE COLUMN.—P. Villard discusses the deflection of the positive light in a vacuum tube, with a view to elucidating its mechanism. In the classical experiment concerning its deflection by a magnet, it is found that the beam is bent out toward the region between the poles of the electromagnet somewhat like an elastic band. It behaves like a filament carrying a current. In this phenomenon the walls play a prominent part unless the tube is very wide. In a wide tube the positive particles no longer behave like a conducting filament. Their paths twine round the lines of force of the magnetic field in such a manner that they diminish the field. A conducting filament, on the other hand, rolls itself up in such a manner as to increase the magnetic field. When the field is increased the spirals described by a projected particle diminish in diameter, whereas those of a conducting filament increase. If the positive column consists of particles at rest, or in very slow motion, it may be regarded as a conducting filament. Its positive charge is evidenced by its attraction by a negative pole, and its repulsion by the walls. Its length is increased by increasing the current strength or narrowing the tube. —P. Villard, Comptes Rendus, March 19, 1906.

E. M. F. BETWEEN METALS AND LIQUIDS.—When a sensitive electrometer is connected with an insulated metallic vessel having a glass orifice from which a conducting liquid, say, a solution of magnesium sulphate, escapes drop by drop, the electrometer shows a small deflection which attains a steady value after several minutes, and continues as long as the liquid drops. The deflection varies with the metal and the liquid, and, according to C. Nordmann, constitutes a simple expedient for determining the contact E.M.F. between a metal and a liquid. The limiting value of the electrometer deflection is independent of the capacity of the system and of the rate of flow. It depends, however, upon the temperature and upon the state of the surfaces. This variation must be taken into account in the author's "ionograph," employed for registering the ionization of the atmosphere. The author has succeeded in circumventing it by letting the droplets fall into a smaller vessel having a similar orifice. Whatever charge the smaller vessel receives owing to the contact potential it gives up again automatically, since drops of the same number and radius enter it and leave it. The smaller vessel is connected with an electrometer, and the readings of the latter are thus given a very stable zero, and they directly indicate the ionization of the atmosphere.—C. Nordmann, Comptes Rendus, March 12, 1906.

* Compiled by E. E. Fournier d'Albe in the Electrician.

SCIENCE NOTES.

A subject of national importance is the problem of diet. The first attempt to deal with the matter from the scientific side was made by a great chemist, Liebig. We are now in a position to investigate the problem more minutely, and the work of American physiologists has already led to important results. We have still to learn how materials such as rice and potatoes, which are nearly free from proteids, continue nevertheless to serve as the main diet of large numbers of people. It would seem that the best plan of operations will be for physiologists to settle by the accurate methods now available the precise value of typical foodstuffs, and for the chemist to deal with these in relation to their composition, and finally with reference to the constitution of their constituents. The time has come when an advance must be made from the chemical side in the analytical methods employed for gaging the value of food materials.

The late Prof. Thomas M. Drown divided all waters into two classes, namely, normal and polluted waters, and stated, as regards normal waters, that although they differ very widely in character from the pure colorless mountain brook to the dark-colored water from swampy ground, they are all characterized by never having received any contamination connected with man, and although often far from pure waters, differ from a polluted water in one most important respect, in that they are not capable of producing, as far as known, any specific germ disease. It is true that many normal waters, on account of the large amount of vegetable matter they contain, are unfit for household use, although they may be sanitarily safe waters in the sense of not being the vehicle of the germs of disease. Hence the sanitary value of a water analysis depends not on determining the amount of organic matter which a water contains, but on the amount of information it can give in answer to the question, "Is a given water a normal or a polluted water?" or, stated in other words, "How far can analysis determine whether or not the organic matter in a water is of vegetable or animal origin?"

The San, or Bushmen (Bosjesmen of colonial annals), may, with the possible exception of the Kattea, be regarded as the most primitive of the present inhabitants of South Africa; according to most authors, there is no decisive evidence that there was an earlier aboriginal population, although Mr. G. Bertin informs us that Bushman tales always speak of previous inhabitants. The main physical characteristics of the Bushmen are a yellow skin, and very short black woolly hair, which becomes rolled up into little knots; although of quite short stature, with an average height of 1.529 meters (5 feet ¼ inch), or, according to Schinz, 1.570 meters (5 feet 1¾ inch), they are above the pygmy limit of 1.450 meters (4 feet 9 inches). The very small skull is not particularly narrow, being what is termed sub-dolichocephalic, with an index of about 75, and it is markedly low in the crown; the face is straight, with prominent cheekbones and a bulging forehead; the nose is extremely broad—indeed, the Bushmen are the most platyrrhine of all mankind; the ear has an unusual form, and is without the lobe. Their hands and feet are remarkably small.

In 1760 Canton made the discovery that when oyster shells were calcined with sulphur in a crucible at a red heat, there was produced a phosphorescent substance, which he regarded as a form of phosphorus, but which was really an impure calcium sulphide. The so-called "Bologna phosphorus" thus obtained has found a commercial use as the luminous basis of phosphorescent paints. The luminosity does not appear to be due to a slow process of oxidation, since it has been found that a preparation that had been sealed up in an air-tight tube for a century still phosphoresced. Zinc sulphide has the same property of being luminous in the dark. According to Knowledge, it has recently been observed by Signor Vanino that the phosphorescent sulphides of calcium or zinc can act upon a photographic plate in the dark through a layer of black paper, but that all action is checked by placing celluloid between the substance and the sensitive film. Since radio-active preparations of lead can act readily through celluloid, it would seem that the action of the phosphorescent sulphides on the plate is not due to β or γ radiations (which can pass through celluloid), but to traces of sulphureted hydrogen, given off by the sulphides,

being capable of penetrating the paper, but not the celluloid. Signor Vanino also finds that the presence of calcium fluoride enables one to obtain an actively phosphorescing sulphide at a much lower temperature than is commonly used. The preparation may also contain a large amount of inert substance, and only a small proportion of calcium sulphide, and yet be very luminous.

ENGINEERING NOTES.

While it is a fact, with which heating engineers are familiar, that every 10 deg. rise in the feed-water temperature corresponds to about 1 per cent saving in fuel, this gain in economy is apparently frequently overlooked by manufacturers and owners. Feed-water heaters faulty in design or of insufficient capacity are installed; live steam is used where exhaust would do as well; condensation is allowed to go to waste which could easily be utilized; and heat units which should be saved are lost in other ways.

The first heat of Bessemer steel made in America was produced in an experimental plant at Wyandotte, Mich., in the autumn of 1864, and the first commercial rolling of steel rails was in the Cambria Iron Company's mills at Johnstown, Pa., in August, 1867, from steel made by the Pennsylvania Steel Company, at Steelton, Pa. The development of the business was very rapid, but not always attended with profitable results. In June, 1876, there were ten rail mills in operation and an eleventh nearly ready to start. At that time one Bessemer company had already gone to the wall. One of these ten companies, as well as the eleventh, and their work, have absolutely gone out of existence. In fact, but five of them are now making rails. One of these has but a limited production in that department, and the other four are making their rails in mills not then in existence, and in one case in a mill hundreds of miles away. It is also true that three of the then separate corporations have since been consolidated, under a new title, into one which, with its new mill, is enumerated in the existing five, and this mill is situated some miles from the situation of either of the original ones. Two of the other companies, while actively at work in other lines, have ceased making rails. Since 1876, in addition to those already mentioned, seventeen corporations have erected mills to roll standard weight steel rails, thirteen from steel of their own manufacture, and four from purchased blooms. Seven of the steel producers are now making rails, two are on other product, and the remaining eight have gone out of existence, so that there are now in the United States ten corporations running thirteen rail mills. Of these, one company is rolling its rails from basic open-hearth steel, and another one from either that or Bessemer. We only refer to mills roiling rails of 60 pounds and over per yard.

The American Institute of Social Service will hold in New York city, in January next, an exposition of devices for safeguarding the lives and limbs of working men and women, and for preventing accidents under the ordinary conditions of life and labor to which the general public is exposed. This will be the first exposition of the kind in the country. In 1889 there was a German exposition for the prevention of accidents. In 1893 an exposition of this nature was held in Amsterdam, and since then there have been several similar expositions in continental Europe and in Canada. As an outgrowth of these national movements there have been organized several museums of security; one at Vienna in 1890, one at Amsterdam in 1893, one at Munich in 1900, one at Berlin in 1901, and one at Paris in 1905, and Russia has recently established a museum on a large scale in Moscow. Following are some of the groups of exhibits: Section 1, models, photographs and drawings of scaffolding, as well as the personal equipment of workers in building trades; (2) protective devices for boilers, water gages, signal apparatus, boiler and pipe valves, protective devices for electrical machinery and acetylene apparatus; (3) protective devices for motors and power transmitters, devices for turning on power and shutting it off, belt connection, coupling, etc.; (4) fire protection and the prevention of explosions; (5) first aid to the injured; (6) mining and quarrying, devices in use on stone crushing machinery, etc.; storing of explosives; (7) metal industry, safety devices for metal working machinery; (8) textile industry, safety devices for looms, carding etc.; (9) leather and paper industry, safety devices for paper cutting, stamping and molding machinery; (10) safety appliances for elevators and hoisting apparatus models; (11) food products, safety appliances for kneading machines, rollers and cutters; (12) personal equipment of workingmen, protective spectacles, respirators, suits, etc.; (13) workingmen's dwellings; (14 and 15) housing, models, plans, photographs; (16) ventilation; (17) models, photographs and plans of toilets, dressing and living rooms, baths, etc.; (18) cooking, demonstration in heating food, models, plans, photographs; (19) other social betterment institutions, reports of labor departments, industrial arbitration courts; (20) agricultural machinery, safety appliances on same, demonstrated by models and views; (21) lumber industry, safety devices for band and circular saws, planing machinery, etc., demonstrated by models; (22) models, photographs and plans of workingmen's industrial betterment institutions of all kinds. Requests for information regarding space can be made to Dr. William H. Tolman, director, 287 Fourth Avenue, New York.

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